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Yield of Sugarcane in Louisiana as Influenced by Soil Moisture Status Andclimate.

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YIELD OF SUGARCANE IN LOUISIANA AS INFLUENCED BY SOIL MOISTURE STATUS AND CLIMATE

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ABSTRACT

Sugarcane in Louisiana lies at about the farthest northerly limit of its cultivation in the world. The crop is almost entirely unirrigated and is thus fully exposed to the climatic effects. This study was undertaken to find out the relationships of soil moisture status and of the climate on sugarcane yield per acre and recoverable sugar per ton of cane.

Mean yields per acre and recoverable sugar per ton of cane for the State of Louisiana and for 13 of its parishes for the years 1936-60 were studied. The mean monthly precipitation and temperature from 12 weather stations in the sugarcane area were used for the study of relations of the state data. Daily weather data of individual representative weather stations were used for studying the relationships in each parish. Associations with spring and fall freezes were also studied.

Available water storage capacity of the soils under sugarcane was taken as four inches. Soil moisture balance was worked out daily for each parish by computing evapo-transpiration by a method developed in this study. The method involves modulation of Thornthwaite's potential evapo-transpiration due to differential vegetation cover and soil moisture tension variations. Each day was classified on the basis of its computed water balance. Days with precipitation in excess of the assumed moisture storage capacity were termed moisture surplus days. Days with assumed available water between 1.5 and 4.0 inches were called days with favorable soil moisture,

and days with assumed available moisture below 1.5 inches were called moisture deficit days.

Comparative correlation studies of cane yield for the state over the two periods 1919-35 and 1936-59 showed significant differences in response to rainfall of the preceding November-February period, mean February temperature, and rainfall and temperature for March. Mean cane yield for the state for 1936-60 was negatively associated with moisture surplus in March-October. Recoverable sugar per ton was negatively related with mean August temperature.

Results of total correlation studies for 13 parishes with 37 variables comprising soil moisture and temperature conditions over the entire period of growth showed considerable variation. The parishes studied have been classified into four groups on the basis of soil moisture conditions and relationship with cane yield and sugar per ton cane.

Moisture surplus in March and April was inversely related with cane yield in 9 parishes, the negative trend missing the level of significance in the remaining four parishes. Moisture surplus days for these 4 parishes had a positive association with sugar per ton cane. Day degrees were positively associated with yield in the two most humid parishes, signifying relationship of moisture surplus and day degrees.

Mean temperature for August was inversely related with sugar per ton in all of the parishes except those exposed to considerable moisture deficit. Cane yield was inversely related with August temperature in the least humid parishes. The available data for sunshine did not show any relationship with either cane yield or sugar per ton cane.

Need for studying the physical properties of soil, soil temperature and related growth data of sugarcane in relation to soil moisture surplus has been stressed. It has been suggested that the mechanism of negative association of mean August temperature with sugar per ton of cane be studied.

On the basis of soil moisture computations, and correlation studies of soil moisture deficit with cane yield, irrigation may be worthwhile in Lafayette, Vermillion, Rapides and Avoyelles Parishes. There did not appear to be any need for irrigation in Assumption, Iberia, St. Mary and Terrebonne Parishes.

INTRODUCTION

Sugarcane is a warm weather, sun loving plant and its cultivation is limited to an equatorial belt about 30° north and 30° south latitude. Sugarcane in Louisiana is grown at about its farthest boundary in the northern hemisphere. It was in this context that MacDonald (74) stated that the crop in this country was being grown under limiting conditions of climate. Relatively small changes in climate from year to year can lead to big differences in crop behavior.

An examination of the history of sugarcane cultivation in this country shows a definite shift in the area under sugarcane utilized for manufacture of sugar (Table 1). Sugarcane cultivation for sugar production on the mainland is now confined to Louisiana and Florida. Texas, South Carolina, Mississippi, Georgia and Alabama no longer produce sugar. The small area under sugarcane in these states, as also the area in North Louisiana is utilized for syrup.

Sugarcane is known to have a high water requirement. Stubbs (105) estimated that 56 acre inches of water was required for a 45 ton per acre crop and strongly advocated supplemental irrigation for Louisiana. Actual water requirement for sugarcane in Louisiana has not been determined, but based on water requirement for the crop, under Hawaiian conditions (11), about 36 inches are required for an average crop of 22 tons per acre with 8.2 per cent recoverable sugar.

The average rainfall for the sugarcane area of Louisiana for the period April through October over the years 1936-60 was $36.6 \pm .70$

Table 1. Area Under Sugarcane in Mainland United States of America (1,000 Acres)

		Area Harvested in 1,000 Acres For						
		1899	1929			1959		
S.No.	State	Total	Sugar	Sirup	Total	Sugar	Sirup	Total
1.	Alabama	32.87	--	17.86	17.86	--	2.99	2.99
2.	Arkansas	.46	--	--	--	--	--	--
3.	Florida	13.80	10.43	--	10.43	46.89	1.74	48.63
4.	Georgia	26.06	--	28.55	28.55	--	3.27	3.27
5.	Louisiana	276.97	195.22	10.17	205.39	251.28	3.64	254.92
6.	Mississippi	11.55	--	17.00	17.00	--	2.17	2.17
7.	N. Carolina	.03	--	--	--	--	--	--
8.	S. Carolina	7.34	--	4.59	4.59	--	.33	.33
9.	Texas	17.82	--	6.72	6.72	--	.37	.37
10.	Others	.09	--	.91	.91	--	--	--
	Total	386.99	205.65	85.80	291.45	298.17	14.51	312.68

SOURCE: 1. Statistical Abstract of U.S., 1915.

2. Census of U.S. Agriculture - II, No. 2, 1930.

3. Census of U.S. Agriculture - II, No. 2, 1959.

inches. Based on the above Hawaiian estimate, a year with deficit rainfall would not provide enough water even for a 22 ton crop. On the basis of certain climatological data of New Orleans and precipitation data of other weather stations in the sugarcane area, Van Bavel (112) has computed evapo-transpiration for the area. He reported that for a soil in southeast Louisiana with an available water shortage capacity of 4.0 inches, there is a probability of 20 per cent that the months of May, June and July will have 5, 14, and 6 drought days, respectively.

Sugarcane requires a well drained soil and is not adapted to waterlogged conditions. The adoption of planting in the ridge in cambered seed bed and the provision of adequate surface drainage arrangements for the cultivation of the crop in Louisiana is a testimony of the existence of excess moisture conditions. Van Bavel reported occurrence of excess moisture of up to one inch for 50 per cent of the days in spring, and an excess of 2.8 inches for 20 per cent of the days in both summer and fall.

It will thus be realized that the sugarcane crop in the state, which is almost entirely rain fed, has to be grown between two hazards--excessive moisture and drought. For making a success of the crop, which can tolerate neither excess moisture nor drought, a farmer will have to be able to minimize the effects of both conditions. It is the purpose of this study to develop a procedure for the evaluation of both moisture surplus and moisture deficiency and drought and to determine what effect these conditions have had on yield of sugarcane and amount of sugar produced per ton of cane. Since the water-use of a crop depends so much on the climate, an integrated study of the climate and soil moisture balance was felt desirable.

However dominant a single variable may be in crop behavior, yield per acre is bound to be influenced by other important variables, in particular those which have significant effect on the dominant variable under study. For this reason, the study has been extended to include the effect of fertilizer nitrogen and the level of borer injury on the yield of sugarcane and sugar per ton of cane.

The northerly location of the sugarcane area, with its freeze and low temperature conditions over a part of the year, has imposed the existing pattern of fall planting and fall harvesting. The same conditions together with conditions of precipitation from September to December are responsible for poor or even lack of ripening conditions and loss of cane yield. This aspect of the climatic effect has also been studied.

REVIEW OF LITERATURE

Climate and crop behavior

Climate profoundly affects the natural vegetation. Natural vegetation has been even used to classify climate, e.g. Rain Forest climate, Tundra climate (64). Climate is often a decisive factor in the regional distribution of crops and influences their yield and quality. As far as sugarcane is concerned, the distribution of the crop on the globe is ample testimony of the effect of climate. The work in Hawaii (11), Mauritius (46), India (80), Indonesia and Barbados (29), have served to highlight the climatic factors, some of which are reviewed below.

Temperature is usually taken as the most important weather element in deciding the range of vegetation belts. The limiting influence of temperature results primarily from the length of period of favorable temperature, the occurrence of too high or too low temperature, or temperature conditions favorable for diseases and pests. Each crop has generally 3 cardinal temperatures, viz., a minimum, a maximum and an optimum, although these values are much influenced by many other factors.

Precipitation influences vegetation primarily through its effect on soil moisture regime. Its distribution, intensity and duration in relation to the age of the crop are as important as its total. Light, being essential for photosynthesis and transpiration, is of considerable consequence. In case of flowering plants, photoperiod requirements in relation to the light conditions influence the time required to flower. Relative humidity has much to do with the rate of water usage by the plant (29). Wind speed assumes great significance when it reaches hurricane speed, particularly when the crop is well developed, when it leads to large scale lodging (127).

Effect of weather elements on sugarcane

The effect of each important element of weather on sugarcane will now be reviewed.

1. Temperature. Sugarcane is affected by air temperature as well as by the soil temperature of the root-zone. Hawaiian work showed growth to be almost linearly related to air temperature over the range 56-74^{o}F, if the soil temperature was not limiting, i.e., above 70^{o}F. The optimum temperature for growth was found to be 80^{o}F. Cooling of the soil led to nitrogen deficiency in the leaf even with a plentiful supply of nitrogen in the soil and a decrease to 1/3 in the uptake of phosphorus. Low soil temperature conditions also favored loss of nitrogen and potash through leaching (49). Earlier work by Das (24) in Hawaii, Das and Halais in Mauritius (27) and Evans (36) also showed a close linear relationship of growth with temperature between 62.6^{o}F and 73.4^{o}F. Day degree concept of Das (25) was utilized to predict yield of cane and sugar with a fair amount of success, although Wadsworth (128) found a number of locations with poor association ($r = .455$) between cane yield and day degrees. MacDonald (74) in Louisiana did not find any significant relation of temperature for April-November with sugar yield per acre, but the temperature for July and August was found to be positively associated significantly with recoverable sugar per ton cane. These studies related to the period 1895-1924.

Soil temperature during germination is of great consequence. Hawaiian work (11) sets the minimum at 70°F, the optimum at 93°F and a temperature of about 100°F as harmful for germination. In Louisiana Ryker and Edgerton (29) found 54°F as the minimum and Rands and Dopp regarded 78°F as the optimum. Rege and Wagle in India (29) found 50°F as definitely too cold, although instances of germination have been cited at this temperature (29). There does not appear to be any agreement on this aspect of the effect of temperature.

Temperature conditions during ripening and harvesting period are important, as far as recoverable sugar per ton cane is concerned. Clements (17) pointed out the beneficial effect of chilling in the night, a high diurnal range with a relatively mild maximum temperature for the day. Too low a temperature in the fall was found to induce killing of buds, foliage, and shoots, inversion of sugars and splitting of cane in Louisiana (67), while spring freeze and generally low temperatures in spring were found affecting stands (3). The same effect was reported by Dutt (32) and Adhlakha (2) for West Pakistan and northwest India, although to a less degree due to less severe conditions. Whereas the relatively hard and frequent freeze conditions have imposed on Louisiana its fall planting in preference to the earlier practice of windrowing the seed cane, the farmers in northwest India and West Pakistan have to face poor germination and lower sugar per ton cane in years with considerable frost and light freeze because of their practice of spring planting. MacDonald (74) found a significant positive association ($r = .53$) between mean March temperature and yield of sugar per acre. January and February temperatures were also found to be positively related (r = .34 and .27, respectively). A higher temperature during this period was believed by him to favor good stands. Lyons (73) in Georgia also reported a positive relation of .547 for mean March temperature and yield of cane over the period 1937-1956.

2. Precipitation: Precipitation affects sugarcane by influencing the soil moisture, by affecting the relative humidity and is also associated with varying degrees of loss of sunshine. Early work by Rawson, Tengwall and Van der Zijl, Smit Sibinga, Sun and Chow, Walter and Leake, all cited by Dillewijn (29) attempted to show the effect of total precipitation, the quantity received during growing season and ripening period, and the intensity and duration of showers. Halais (46) in Mauritius worked out the effect of an excess or a deficit over and above the normal rainfall of growing season and the ripening period on the yield and sugar content. Significant relations were observed by him enabling him to predict the decrease in cane yield or increase in sugar per ton cane by a deficit of one inch from the normal rainfall of the growing period. An excess in the ripening period was found to pull down sugar per ton, but did not influence cane yield.

MacDonald (74) found rainfall for antecedent November, January, and February to be negatively associated significantly with sugar yield per acre (r = .32, -.51 and -.35, respectively), and concluded that wet conditions at the beginning of the crop marked low production years. Relation with precipitation for July, August, September, October, November and December was poor. Edgerton and Tims (36) confirmed the above conclusions for the period 1911-1924.

Khanna and Sehgal (62) and Acharya et al. (1) studied the influence of weekly rainfall on sugarcane yield at Daudpur and Pusa farms in Bihar (India) for 18 and 21 years, respectively. Orthogonal polynomials of the fifth degree were fitted to each year's weekly rainfall data from the first week of January to the first week of October. Slow secular changes in yield, as also rainfall distribution constants were eliminated by fitting smooth curves to these data. Multiple regression coefficient, however, failed to attain significance level. Indications of the beneficial effect of summer rainfall and deleterious effect of rainfall during January and the first part of February have been pointed out by them. Sanjeevi (94) opined that the poor sugar per ton of cane in parts of Madras state (India) was due to wet weather and excessive rains at the time of harvesting. Although mean rainfall data were given, no correlation coefficients were given by him. This view of the deleterious effect of excess moisture conditions on sugar per ton was also expressed by du Toit (33) for South Africa.

The great effect of the total amount and distribution of Monsoon rains on sugarcane yield and sugar recovery in Uttar Pradesh, India is stressed in the Annual Reports of the Cane Department of the State (120). This effect is more marked in east U. P., where the crop is primarily unirrigated. Low cane yields, high sugar per ton and very short grinding season marked years with late break of monsoon. The data have, however, not been analyzed statistically.

Lyons (73) found the precipitation for April to have a highly significant positive correlation coefficient of .627 with cane yield. Partial correlation after eliminating the effect of mean air temperature for April worked out to .614, which was significant at the 5 per cent level of probability. The beneficial effect was ascribed to possible better tillering conditions.

The primary effect of precipitation is on soil moisture. It will thus appear reasonable to follow up the effect of precipitation by computing moisture status during different stages of the crop. Although much work on soil moisture status for sugarcane crop under irrigated conditions has been reported, no such study on the unirrigated crop appears to have been made.

Water use by sugarcane and its relation to precipitation is also influenced by the variety (29). Some varieties stand waterlogging better, while others withstand drought tolerably well (32).

3. <u>Sunlight</u>: The effect of sunlight has been studied intensively in Hawaii. Das (26) studied the performance of sugarcane in lysimeters at low land, Makiki (high sunshine) and upland Manoa (low sunshine) using the same soil. The lysimeters at the latter station with less than half the sunlight of the former, but with only $4^{\circ}F$ difference in maximum temperature and the same minimum temperature produced only one-third of the cane produced at the former location. Borden (29) confirmed these results. Further work by Clements (29) stressed the importance of intensity of sunlight. It was also found that efficiency of utilization of heat and sunshine increased at higher intensities of light. Brandes and Lauritzen (10) and Lauritzen et al. (67) reported the relationship of light requirement and temperature. Higher temperature called for higher intensity of light and although this is usually the case in the field, any increase without the required increase of light intensity will, according to

their results, not be conducive to growth.

MacDonald (74) studied the relation of sunshine data for New Orleans on yield of sugar per acre and sugar per ton in Louisiana. A correlation coefficient of .30, .36, and .27 was found between sugar per ton of cane and mean monthly sunshine for July, August and September, respectively. Yield of sugar per acre had a negative correlation coefficient of .27 and .29.

Relative Humidity: Hill and Evans (52) found a significant negative relationship between growth and relative dryness of air. This was attributed to its influence on water-requirement of the crop. Sugarcane has a peculiar feature of being able to absorb substantial quantities of water through its leaves when the soil in the root zone is dry (128). This enables it to benefit from light showers or even heavy dew.

Wind Speed: Besides its influence on evapo-transpiration, a wind speed above 30 miles per hour is harmful, even for short periods. Areas exposed to such weather have to look for varieties particularly resistant to lodging and may have to resort to earthing and propping (127). Arceneaux and Hebert (5) have studied the effects of breakage of canes in Louisiana and developed formulas to assess the damage by hurricanes.

Before closing this review of the effect of climatic elements, it may be pointed out that the different elements described above are much related and influence the crop in a markedly integrated way. This has led to the concept of different "climates." Twenty-four such climates resulting from combinations of 4 root and 3 air temperatures at 2 light intensities have been studied in Hawaii with some very interesting results (11). The crop-weather stations organized in India (80) measure the micro-climate of the crop together with related germination, growth and other development data for the crop concerned. However, data were reported to be too limited to enable conclusions.

Climate of the sugarcane area, Louisiana

The climate of Louisiana was described by Sanders (93) and included the area in which sugarcane is grown. Earlier accounts relating to the sugarcane area were given by Stubbs (105), MacDonald (74), and by Blume (9). Maps depicting mean date first freeze (fall) and mean date last freeze (spring) have been published by the U. S. Weather Bureau. Based on the data for 11 weather stations, listed in Table 2, representing rural conditions of sugarcane growing, some features of the climate as it influences sugarcane are given.

Cheneyville shows definite continentality in relation to Houma by its higher mean July maximum temperature (93.2^{o}F) and a lower January minimum (41.2^{o}F), as compared with corresponding figures of 90.7^{o}F and 46.1^{o}F for Houma. Houma has an annual range of 24.9^{o}F as against 30.0^{o}F for Cheneyville. Precipitation also shows the same trend. Cheneyville is rainier in cold weather and early spring while Houma has maximum rain in summer (July and August). Other stations also show the effect of distance from the Gulf.

Temperature variations over the period 1936-60 were studied for the entire sugarcane area. The months of May to September showed much less variation as compared with February, March, October, and November. February was found to have the biggest variation (56.0 $\pm$ .42). July or August was the hottest months while January or December and occasionally even February was the coldest month of the year. Although the mean temperature during April-October varied only from 76.1^{o}F at Melville to 76.9^{o}F at Franklin, the mean date of the last spring freeze for these two places differed by a month. The average values for 30 years (1921-50) for date of last spring freeze, first fall freeze, occurrence and number of days between these two occurrences and the probability of such occurrences are given in Table 2. It may be noted that Reserve with mean last freeze on 2/11 and first fall freeze on 12/13, giving 306 days between these two occurrences, is least susceptible to frost hazard. Franklin is a close second. The other extreme is provided by Cheneyville with only 248 days as the frost-free period. In general the probability of a fall freeze is less than that of a spring freeze. Jeanerette and Angola both had 271 frost-free days, but Jeanerette is more exposed to fall freeze, while Angola suffers more from spring freeze. The data are presented graphically in Figure 1.

Data for relative humidity are limited. On the basis of mean data of Ryan Air Port in Baton Rouge, relative humidity is high all through the year. October, with 47 per cent relative humidity at noon is the driest, while July has highest relative humidity. Wind speed, on the basis of mean data of Ryan Air Port, is maximum (10.4 M.P.H.) in February and lowest (6.3 M.P.H.) in July. Low wind speed in July together with high relative humidity is conducive to checking increased evaporation, in spite of slightly higher temperature for July.

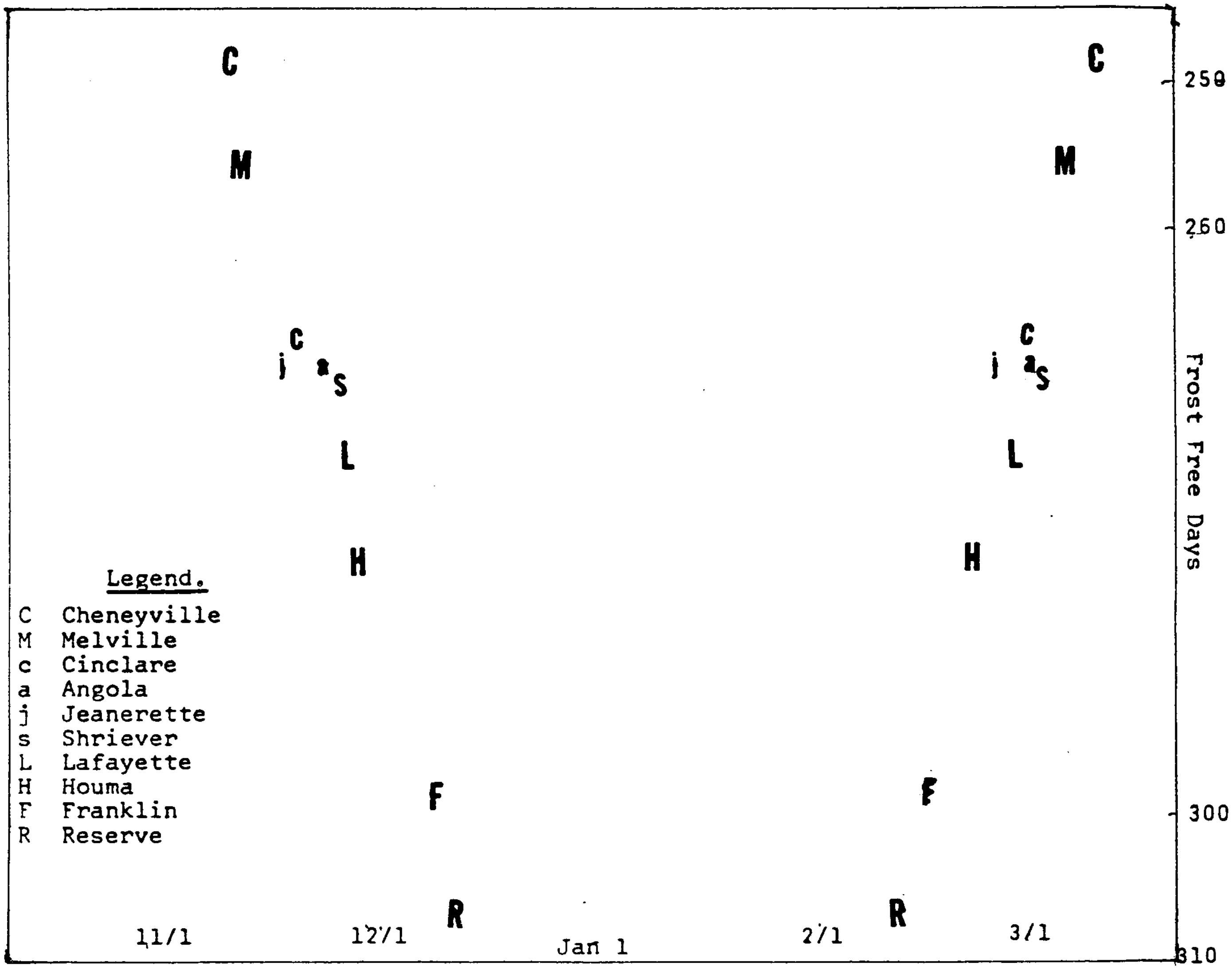
Sunshine data are available for New Orleans only and the mean data shows October as having the highest percentage of hours of possible sunshine (69%) with the lowest (46%) in December. July and August tend

Table 2. Freeze Data for 32° F. Threshold for Sugarcane Area, Louisiana.

Location	Mean Date of Last Spring Occurrence	Mean Date 1st Fall Occurrence	Mean No. of Days Between Dates	Years of Record		No. of Occurrence	
				Spring	Fall	Spring	Fall
1. Houma	2-21	11-30	282	30	29	29	25
2. Shriever	3-2	11-27	270	29	30	29	26
3. Reserve	2-11	12-13	306	30	30	28	20
4. Cinclare	2-28	11-22	267	30	30	30	29
5. Angola	3-1	11-25	269	29	28	29	27
6. Melville	3-5	11-15	255	30	30	30	29
7. Franklin	2-15	12-10	298	29	30	27	21
8. Lafayette	2-26	11-27	275	30	30	30	27
9. Abbeville	2-26	11-28	275	27	26	27	23
10. Jeanerrette	2-24	11-20	269	24	24	24	22
11. Cheneyville	3-11	11-13	248	30	30	30	30

SOURCE: Ralph Sanders. Climates of the States--Louisiana (U.S. Dept. of Commerce, Weather Bureau, Climatology of U.S. No:60-16), December 1959. The data relate to the period 1921-50.

Figure 1. Mean Frosty Period of Weather Stations in Sugar Cane Area of Louisiana



to have less sunshine (58 and 59%, respectively). Sunshine is not related to precipitation uniformly for all the months.

Soil moisture and sugarcane

Water is the most abundant constituent of sugarcane, comprising more than 70 per cent of its fresh weight. Much larger quantities are needed as transpiration, variously estimated at 200-300 lbs. for every pound of dry matter. The evapo-transpiration is still higher, being about twice as high as transpiration (29). Almost all this large quantity of water is drawn by the plant from the soil through its roots. Soil moisture affects the sugarcane plant both directly as well as indirectly (11). Direct effects are due to the deficiency leading to cessation of cell elongation, loss of turgor and ultimate death of the plant cells. Indirect effects result from poor aeration, leaching away of plant nutrients, lower soil temperature, poor or even lack of microbial activity, possible accumulation of soluble iron under conditions of excess moisture (89), and the effect of diseases and insect pests (43, 60, 76). Lack of oxygen will also disturb uptake of minerals and even water absorption due to the roots not being able to carry out normal respiratory processes (129). Dry conditions check growth and often lead to fixation of potassium and occasionally even phosphates (35). Thus a suitable balance of soil moisture in the root zone of growing plants is necessary for healthy, vigorous growth. What constitutes a "suitable balance" will be taken up later.

The absorption of water by roots is believed to be of two types--passive and active. When the entry of water into roots is brought about by conditions originating in the top of the plant and root cells play only a subsidiary role, it is termed "passive." Absorption is called "active" when the mechanism is located in the root system leading to root pressure, as a result of the difference in osmotic pressure of xylem sap and soil water. It operates only up to 1-2 atmospheres deficit, while passive absorption continues up to 15 atmospheres generally and even much higher, being limited by the cohesive force of water in the evaporating cells less small loss of this force in its transmission to the root cells. It is obvious that the "active" absorption will lead to uptake of larger quantities readily and the plant is then able to meet large requirements for growth in this range (81). It has been suggested that water relations of the plant be expressed in terms of diffusion pressure deficit (DPD) that develops, as plants' behavior depends largely on turgor conditions of its cells (65, 99). However, lack of a suitable method has limited the use of this approach.

An important function of the soil, therefore, is to act as a storage reservoir for water between rainfalls or irrigations, and to supply water to the roots in accordance with their daily requirements. The water storage capacity of a soil is expressed as acre inches of water that the soil can make available to the plant. This quantity depends on the depth of the soil utilized by plant roots for moisture extraction and available water per unit layer of the soil. Water held by a soil is expressed in terms of the pressure against which it is retained on a semi-permeable membrane in a pressure cell and thus provides a uniform basis in terms of the energy basis of moisture absorption by roots, as discussed earlier. Moisture held by a soil at 15 atmospheric tension, generally corresponds with the lower limit of water availability, while the quantity held at field capacity and corresponding to 1/10-1/2 atmosphere tension, marks the upper limit of availability. The quantity of water between these two limits is taken as the available water, and when computed for the rooting depth, as mentioned earlier, represents total available water that a soil can store.

Slatyer (98, 100), Kramer (65) and several others showed that the lower limit of water availability did not always correspond to moisture at 15 atmospheric tension, but varied with the nature of the plant and even the environment. Slatyer found that diffusion pressure deficit determination on the plant provided a better basis for determining when the plant could no longer take up enough water from the soil.

The depth of soil utilized for moisture extraction by a plant is very largely a function of the nature of its roots and their depth. Both of these in turn depend on soil conditions and agronomic conditions, in particular those of moisture, fertilizer application, tillage (77). Varieties were found to have considerable influence (29). In the sugarcane soils of Louisiana, roots were observed at depths of 36-42 inches in light, relatively well drained soil, and at shallow depths of 18-24 inches in heavy silty-clay soils (97). The presence of traffic pans influenced greatly the root systems in Hawaii (115). Moisture extraction and rooting depth were found to be so closely related as to lead Hawaiian workers to chart the plant roots by following water extraction by the use of gypsum blocks.

Russel (90) reported that at Rothamsted a pasture obtained 3 inches of water from the area actually traversed by roots, and an extra one inch from the wet layers of soil below the roots. This one inch of soil-water had moved to the drier root zone in consequence of considerably lower moisture tension of the lower layer. In view of the very low rate of capillary conductivity at moisture-tensions above 1/3 atmosphere, this component of available water was, however, not considered important by Richards and Wadleigh (89).

Schematic representations of the effects of spatial density of roots on the relation of growth to the apparent depletion of available moisture were presented by Hagan (45). He expected the great diversity in nature and the depth of roots to affect moisture extraction from the soil in a marked way.

Availability of water between field capacity and wilting point and its effect on sugarcane

The total available water in soil lies at tensions varying generally from 1/3 atmospheres to 15 atmospheres. The question of the rate of its availability for evapo-transpiration and of the effect on crop behavior at different moisture tensions within this range has been a controversial issue for the last 30 years. Kelley (61) and Stanhill (103) reviewed the subject, while Kramer (65) offered an explanation of the controversy in terms of diffusion pressure deficit of the plant. Veihmeyer and Henderson (125, 126) maintained that all the water between field capacity and permanent wilting point was equally available and equally effective for growth. Slatyer (99), Taylor (112), Bierhuizen (7), Bahrani and Taylor (6) and Doss et al. (31) found growth hampered much earlier than 15 atmospheric tension was reached. Water usage was found to be strongly influenced by moisture tension between field capacity and permanent wilting point by Makkink (75), Carlson (13), Larsen (66) and Letey et al. (71). Van Bavel (122) found growth of tobacco adversely affected at tensions above 0.8 atmospheres. Slatyer (99) found the evapo-transpiration inversely related to moisture tension for cotton, peanuts and sorghum. Carlson's (13) and Larsen's (66) data also showed an inverse linear relationship of E.T. with soil moisture tension.

Vaadia et al. (121) and Letey et al. (71) have stressed the need to view the whole matter of water availability from a dynamic point of view, i.e., the supply of water by roots per unit time in relation to demand by the plant and availability of water in the soil. The following quotation from the paper of Latey et al. (71) provides their conclusions on this controversial subject:

> When the transpiration rate is low or when the soil moisture potential is high, the effect of soil moisture variations upon water deficit can be expected to be slight, since soil moisture is not the factor limiting transpiration. Under high transpiration conditions (high light intensity, high temperature, low external vapor pressure), the effect of soil moisture tension can be expected to be great.

As far as sugarcane is concerned, Clements (18) reported growth to be optimum at 0.25-0.30 atmospheres moisture tension. Fuhriman and Smith (39) in Puerto Rico reported a yield of 93, 62, 50 and 33 tons per acre when irrigation was given at 1/3, 2, 6 and 12 atmospheric tensions, respectively. The respective mean daily water use was reported as .35, .27, .21 and .19 inches. Wadsworth (128) irrigated his lysimeters on reaching wilting point, 4 days after reaching wilting point and 8 days after reaching the wilting point. The respective cane yields were 75.6, 72.8 and 69.0 tons per acre. The less often irrigated plots however, were found to be higher in sugar per ton of cane and resulted in sugar per acre yields of 9.2, 9.1 and 8.8 tons, respectively. Total number of irrigations were 7.73, 5.21 and 4.66, respectively which led them to conclude in favor of withholding irrigation. Later detailed work (49) showed that growth of cane was definitely hampered at moisture tension of 4.4, and started falling off soon after a moisture tension of 1 atmosphere.

Soil moisture classification

The question of defining a suitable balance of soil moisture in the root zone for sugarcane may now be taken up. Dolgov (30) delimited soil moisture in 6 classes as follows:

1. Unavailable to plants with upper limit near maximum hygroscapacity.
2. Difficultly available and unproductive with P.W.P. as upper limit.
3. Available, but low productivity.
4. Permits normal growth with upper limit being minimal moisture capacity.
5. Easily available - upper limit varies with different plants, but the average coincides with a point, when air occupies 15% volume.
6. Excessive but easily available.

Van Bavel (122) classified soil moisture levels into excess, drought, and the balance constituting the favorable range. A day with rainfall received in excess of the soil storage capacity on the day concerned, was taken as an excess moisture day. A drought day was defined as a 24-hour period in which the soil moisture stress exceeded a limit, which on the basis of experimental evidence, was taken as a point at which the production processes of the crop were being appreciably decreased. In his later work, Van Bavel (123) has taken half the available range, i.e. $\frac{\text{Field capacity - permanent wilting point}}{2}$, as the threshold for drought. Penman (79), Cowans and Innes (21) and Hawaiian workers (96, 109) have also adopted one-half the available range of soil moisture as the threshold of irrigation. Wadsworth (128) in Hawaii called days with soil moisture at or below wilting point as "idle" days, as he believed that growth did not occur on these days because of lack of moisture. His results, referred to earlier, showed, however, that sugar production was not adversely affected significantly, although growth did suffer. It will thus appear that the nature of the crop and climate in which it is grown influences the definition of "suitable" soil moisture, and that for sugarcane, using actual sugar production and not the vegetative growth as the objective in crop production would probably serve to have higher soil-moisture tension as the threshold for "suitable" soil moisture, particularly during ripening.

Water balance of crops

The need to delimit the growth period of a crop into "suitable moisture periods" and otherwise, necessitates working out daily water balance of the soil. This has been done in connection with irrigation needs in arid areas, in general, and to lesser extent for subhumid areas also. Among the various methods reported, mention may be made of Halkias, Veihmeyer and Henderson (47) who proposed frequent soil moisture determination or using a regression with evaporation from black and white Livingston atmometers. Janert (59) worked out potential evapo-transpiration for 10-day periods by his formula and using rainfall records computed the water balances. Thornthwaite (114), Van Bavel (123) and British workers (79) have adopted the system of starting the crop with a soil fully charged with moisture and working out the balances on the basis of precipitation and E.T. as calculated by computational methods.

Methods of determining evapo-transpiration (E.T.)

Any attempt to classify soil moisture in relation to crop growth calls for determination or a correct estimation of its daily moisture requirement or evapo-transpiration. Use of lysimeters (14, 48, 88), water balance method involving determination of soil moisture changes, runoff and leaching (47, 91), vapor flow methods (91) and heat budget methods (108) constitute the most common methods of determination of E.T.

Evaporation rate from a free water surface varies directly with Em - E, when Em and E are saturation vapor pressure of the evaporating surface and the prevailing vapor pressure of the air immediately above, respectively. Evaporation calls for energy to provide heat of vaporization and is thus dependent on temperature (113). The various empirical methods for estimation of E.T. are, therefore, based on one or more of the above factors and those examined for possible use in these studies are listed below:

A) Methods based on mean air temperature: Thornthwaite (113), Blaney, Criddle (22), Hargreaves (22), Holdridge (54), Lowry Johnson (22), Khosla (63), proposed such methods. Thornthwaites' method has been used very extensively and takes into consideration the period of the year in relation to hours of daylight, as determined by the latitude and the heat index of the year. It was used by Holcombe et al. (53) in Louisiana for drought studies on cotton. Howe (56) compared results by Thornthwaite's method in Canada, Australia, Turkey, Argentina, New

Zealand, Rhodesia, and Ireland and concluded that "in no case a truly satisfactory criterion of their validity emerges." Lemon (70) compared Penman, Thornthwaite and Blanney-Criddle method for cotton and reported variations for each, when compared with results from soil moisture data. Van Wijk (124) and Pelton (85) cited fundamental shortcomings of methods based on mean air temperature, and concluded that the results are unreliable for short periods and that results for spring are too high.

B) Methods based on saturation deficit: These methods are in greater use in Europe and Russia and include those of Albrecht, Ivanov, Haude, and Skvortsov (8, 78).

C) Penman's Method: This method (86) takes into consideration mean temperature, relative humidity, hours of sunshine and wind velocity. This method has been much used in various parts of the world, although the fact that more additional basic data are required has been a handicap. Although better agreement of estimated E.T. by this method with actual E.T. was reported by a large number of workers (14, 19, 88, 104), disagreement was also very common (20, 70).

D) Methods based on regression with tank evaporation, and evaporation from Livingston atmometers: Good agreement enabling reliable use of a regression equation with data of Livingston's atmometers was reported by Halkias et al. (47) and Pruit (88). In respect of sugarcane Tamal and Chen (111), reported good agreement with data from Livingston's atmometers. Chang (14) in Hawaii reported a close relationship of E.T. from lysimeters placed in cane fields with tank evaporation. After the crop had covered the land, the E.T. was as high as tank evaporation. These results were at variance with results reported by Cowan and Innes (21) for Jamaica.

Need for modulation of estimates of evapo-transpiration

Most of these methods assume that soil moisture is in plentiful supply and that the ground is uniformly and completely covered with vegetation. These two conditions are not fulfilled for sugarcane in Louisiana at least over its early period of crop history. Fritschen and Shaw (38) reported that empirical methods of estimation of E.T. which are not adjusted for crop development may have serious errors in the estimation of water use of annual crops. They found that $\frac{\text{E.T.}}{E_o}$ varied from 0.10 to 0.82 during the growth of corn, where E_o was open pan evaporation. Chang (14) in Hawaii also reported average $\frac{\text{E.T.}}{\text{Pan Evaporation}}$ to vary from about 0.4 for a one-month old crop to 1.1 for a 10-month old cane crop.

The effect of the increase in moisture tension on water use has already been reviewed. Due to the influence of these two factors on E.T., there have been attempts to modulate the potential evapo-transpiration, as estimated by any of the methods. Mention may be made of Holmes and Robertson (55), which calls for modulation due to dry subsoil, and that of Pierre (87). All these workers have stressed the need and the factors for nodulation; without giving much quantitative data to support the opinions expressed.

Sugarcane soils and cultivation in Louisiana

Sugarcane for sugar manufacture is now cultivated in 19 parishes, and occupies a total area of about 270,000 to 300,000 acres in the southeast of the state with latitude varying from 29.3

to 31.0^{o} north.

Soils under sugarcane in the state were described by O'Neal (84) and those of two parishes in the area as early as 1916. Lytle described soils of Terrebonne and St. Mary Parishes recently. The following classification of sugarcane soils is that of Lytle.*

Soils of Sugarcane Area in Louisiana

Regions	Soil Series	Parishes
1. Mississippi River first bottom soil of recent origin.	Sharkey, Mhoon, Commerce	Pointe Coupee, West Baton Rouge, Ascension, Iberville, St. James, St. John, St. Charles, Assumption, Terrebonne, LaFourche, West Feliciana
2. Mississippi River Prairie terrace soils of Pleistocene origin.	Lintonia, Richland, Olivier	Lafayette, St. Martin
3. Red River Prairie terrace soils of late Pleistocene early recent origin.	Cypremort, Baldwin, Iberia, Jeanerette	Iberia, St. Mary
4. Red River first bottom soils of recent origin.	Yahola, Miller	Rapides, Avoyelles
5. Coastal Prairie terrace soils.	Patoutville, Iberia	Vermillion, Iberia

For the most part, sugarcane in Louisiana is grown in the relatively better drained soils on the natural levees of the streams. The soils are generally fairly heavy in texture and are moderate to

*Mr. S. A. Lytle, Dept. of Agronomy, Agricultural Experiment Station, La. State University, Baton Rouge, was kind enough to look up the distribution of soil series in different parishes, and making few changes, when felt necessary.

poor in surface and subsurface drainage. Physical properties of 7 soils in the sugarcane area were studied by Shuker (97), who reported them to have poor subsurface drainage. His profiles were drawn from Richland silt loams, an Olivier silt, a Baldwin silt loam, a Cypremort silt loam, an Iberia silt loam, a Jeanerette silt loam and a Mhoon loam. The presence of a compact anthropic horizon was pointed out by Shuker. Lund (72) also reported on the physical properties of profiles of the sugarcane area. Moisture held at various tensions was reported, and on the basis of his data, the available water storage capacity is given below.

Table 3. Average Available Water in Inches in Sugarcane Soils of Louisiana.

Soil	Rooting Depth* (Inches)	Available Water	
		1/2 to 15 Atmospheres	1/2 to 2 Atmospheres
Mhoon clay loam	28	4.01	2.02
Sharkey clay	18	4.47	2.44
Commerce loam	36	2.94	1.82
Yahola	30	4.23	2.93
Mean		4.00	2.40

* Author's estimate.

In accordance with his observations, moisture at 1/2 atmospheres tension has been taken as field capacity moisture.

Results of fertilizer requirements of sugarcane were reported by Byrnside and Sturgis (12), by Sturgis (106), and by Davidson (28). The response to 80-120 lbs. nitrogen was general, though not universal.

Phosphate tends to be deficient on terrace soils and response to potash was noted on O'Neal Plantation in St. Mary Parish. Consequently, the general practice is to apply nitrogenous fertilizer in all cases, and phosphate and potash, when indicated. Use of complete fertilizer was indicated west of Bayou Teche (12). Uptake of fertilizer nitrogen was reported to be around 36 per cent (106), as against 50-70 per cent in some other sugarcane growing areas of the world.

Varieties in cultivation since 1936 were listed by Arceneaux (4) and by Hebert (50) for the period 1936-42 and 1941-1960, respectively. Figure 2 reproduced from the paper by Hebert gives the varietal position graphically for the period 1941-1960.

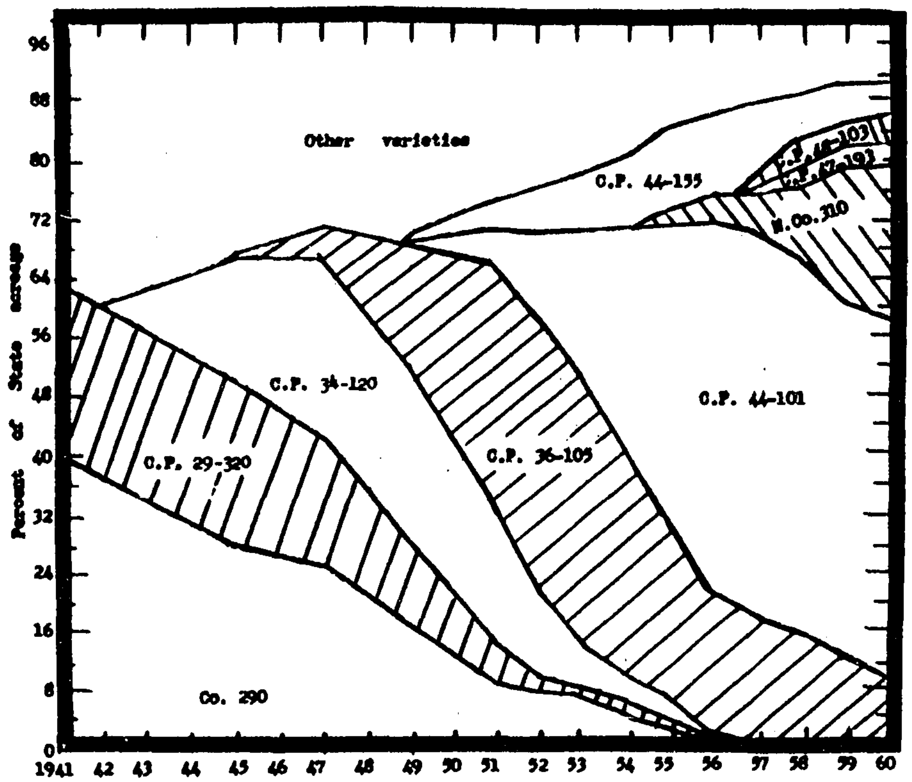


Fig. 2. Changes in the distribution of Louisiana sugarcane acreage among important varieties during the period 1941-1960. (Reproduced from Hebert)

MATERIALS AND METHODS

Collection of yield data and data for sugar per ton cane

The data for average state yield was compiled from U. S. Agricultural Statistics (116), starting with the year 1939, and represent the weighted net yield of cane. With the progress of mechanical harvesting and the weighing of trashy cane, necessary correction factors had been applied to obtain the net cane yield as reported in the above publication.

Data for yield for each parish were compiled from the Sugar Bulletins (107). The data was based on reports made to the American Sugarcane League in connection with proportionate share scheme. These figures were available from 1937 to 1960. The studies for the parishes are thus limited to a 24-year period. Data for sugar per ton of cane were calculated from sugar per acre data and the yield per acre. In both of the above cases, the data referred to cane harvested for sugar manufacture and excluded cane used for seed.

Data for individual varieties at test field locations were compiled from yearly reports on such trials by Arceneaux and Hebert (5) and Hebert and Matherne (51) for Houma, and by Gouaux and Stafford (42) and Stafford (101) for Cinclare and Shirley, who very kindly allowed their use for this study.

Compilation of weather data

An attempt was made to select weather stations in the sugarcane area with long enough records and representing rural conditions of sugarcane growing area. The state climatologist was consulted on the subject and on his advice 12 stations, as listed below, were selected to represent the sugarcane area. The locations of the weather stations are shown in Figure 3.

Weather Stations in Sugarcane Area, Louisiana Utilized in the Study

	Location	Latitude ° North	Station No.	Parishes Represented	Approximate area in acres under cane (1959)
1.	Abbeville*	29.59	0007	Vermillion	1,780
2.	Angola	30.57	0244	West Feliciana	2,210
3.	Carville	30.12	1565	Ascension, Iberville	25,420
4.	Cheneyville**	31.01	1729	Avoyelles, Rapides	3,450
5.	Cinclare	30.24	1807	West Baton Rouge	12,810
6.	Franklin	29.47	3313	St. Mary	31,630
7.	Houma	29.35	4407	Terrebonne	33,550
8.	Jeanerette	29.56	4674	Iberia	31,130
9.	Lafayette	30.12	5026	Lafayette	7,030
10.	Melville	30.41	6117	Pointe Coupee	9,390
11.	Reserve	30.04	7767	St. Charles, St. James, St. John the Baptist	23,950
12.	Shirver	29.95	8295	Assumption	27,090

* This station was discontinued on 10/15/48 and data for Vermillion Lock has been utilized for the period subsequent to this date.
** Cheneyville was closed as a weather station on 10/28/53 and data of Bunkie has been used for later period.

In spite of the care taken in the selection of weather stations, there were periods at various stations when data for temperature and less frequently for precipitation were not available. Periods without precipitation data or temperature data over long periods (10 days or more in a month) were left out. With a view to get the most accurate data for each weekly period, the missing values were substituted by those adjoining stations with essentially similar climatic patterns. The substitutions adopted, as recommended by the State climatologist, were as follows:

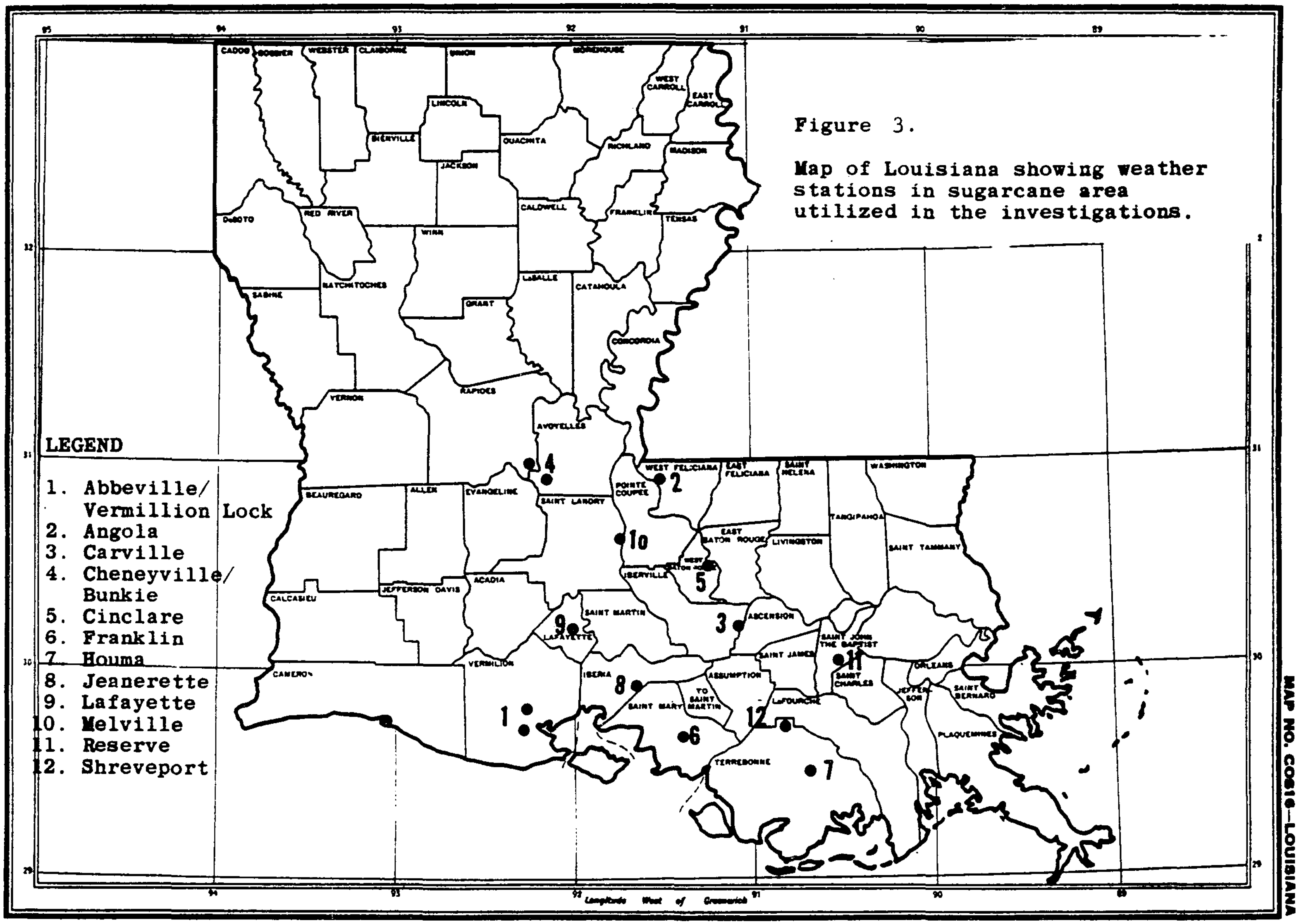


Figure 3.

Map of Louisiana showing weather stations in sugarcane area utilized in the investigations.

Angola for Melville and vice-versa
Angola for Cheneyville (Bunkie)
Houma for Shriver and vice-versa
Franklin for Jeanerette and vice-versa
Crowley for Abbeville
Grand Coteau for Lafayette
Cinclare for Reserve

Data for relative humidity and wind speed from Ryan Air Port, Baton Rouge were utilized for comparison of methods of E.T. for Cinclare Plantation, West Baton Rouge Parish. Sunshine records of New Orleans were utilized for studying the effect on average cane yield and sugar per ton for St. Charles, St. James and St. John.

Compilation of related data

Fertilizer Nitrogen: During the years 1936-1960, one of the most significant changes in sugarcane cultivation in the state has been the increasing use of fertilizers. Data for various grades of mixed fertilizers and straight fertilizers sold in 18 sugarcane-growing parishes were taken from the records of the Chief Chemist, Feed and Fertilizer Laboratory, L.S.U., who maintains a record of fertilizer sales in the state. The quantities sold before 1943 were for a period shorter than one year by 1-2 months (July-August). In these cases, annual consumption has been computed on the basis of average per cent consumption in these months, as based on actual statistics for the year 1960.

The principal nutrient element applied as fertilizer to sugarcane in the state is nitrogen. Nitrogenous fertilizers are used for all soils, being supplemented with green manure for plant cane. As such, nitrogen content of the fertilizers sold in selected parishes and for the whole area were calculated and the data are tabulated as Appendix No. 1. The total fertilizer nitrogen for 18 parishes of the sugarcane growing area was used as an index of fertilizer nitrogen applied each year to sugarcane.

It may be argued that the fertilizer sales in 18 sugarcane growing parishes did not represent nitrogen applied to cane only. This is, of course, true. However, on a relative basis, the quantity consumed in a year did provide a relative measure of fertilizer nitrogen used. Quinquennial statistics of cropped areas were collected to study the trend in crop acreages in the 18 sugarcane growing parishes. On the basis of these data, it was noted that the cropping conditions in only 10 of the parishes, which grew only sugarcane primarily justified the use of fertilizer nitrogen sales data as an index of fertilizer nitrogen used for sugarcane. The parishes thus selected were Assumption, Iberia, St. Charles, St. James, St. John, St. Mary, Terrebonne and West Baton Rouge.

Soils of different available water storage capacity

Outfield test plots under varietal trials of the Agricultural Experiment Station at Cinclare, West Baton Rouge Parish on light soil, Mhoon very fine sandy loam, and on Sharkey clay were selected to see the effect of different available water-storage capacity on the relation of climate and soil moisture status on sugarcane. The yield data, as published in the Sugar Bulletin for each year by Dr. T. J. Stafford was utilized with his kind concurrence.

Profiles were dug to depths of 42 and 30 inches in the Mhoon and the Sharkey soil respectively in a standing test field under 1st stubble cane to study the rooting depth. Roots were examined in the whole profile for their depth of penetration and the extent of ramification. Samples of soil were also taken with a shovel in sections of

6 inches from the profile and washed on a sieve with water to assess the root distribution. On the basis of field examination and the quantity of roots per layer, the rooting depth was estimated as 36 and 18 inches in the Mhoon and Sharkey soils, respectively. Soil moisture retained at 1/2 atmospheres tension was determined. Available moisture capacities were calculated using average values of bulk densities based on Shuker (97) and Lund's (72) data for sugarcane soils.

In accordance with the above, total available water storage capacity was taken as 5.1 and 2.5 inches, and that between wilting point and 2 atmospheres tension as 1.4 and 1.3 inches for Mhoon very fine sandy loam and Sharkey clay, respectively.

Soil moisture status and climatic data classification

The daily weather data, comprising of the maximum and the minimum temperature in degrees Fahrenheit and the precipitation in inches at the weather stations were used to calculate evapo-transpiration (E.T.) by a procedure involving modulation due to extent of vegetative cover and available soil moisture level. The period March through October was taken as the crop-period, since the crop, although planted or harvested in the fall, is killed back during the winter after first germination or sprouting in the case of stubble crop. Preliminary studies had indicated that conditions in March in certain years were quite favorable for growth and a study of the water balance in this month was felt desirable.

The soil was assumed to be fully charged with moisture on the first of March each year. This appeared to be a very safe assumption in view of the average precipitation of about 18-20 inches during the preceding 4 months. A total available soil moisture storage capacity of 4.0 inches was taken as the soil storage capacity, and the quantity held between wilting point and 2 atmospheres was estimated to be 1.50 inches (page 27). Soil moisture balance was calculated for each day of the period March through October by subtracting E.T. and adding precipitation to the water balance in the soil. Precipitation in excess of storage capacity of 4.0 inches was shown as moisture surplus and the day classified as a surplus day. All the excess precipitation was shown as surplus for the same day. It was realized that a heavy rainfall did leave the soil generally in excess-moisture condition for 2-4 days, before the soil drained to field-capacity. Any arbitrary increase in number of surplus days and/or water storage capacity temporarily held would have complicated the working of the program, and exposed the computations to more assumptions. The moisture-surplus data expressed, therefore, unutilized precipitation and "moisture surplus days," as days with runoff and/or percolation of water beyond the root-zone. The need for taking into consideration the total amount, intensity and duration of precipitation, as affecting the utilization of precipitation was realized. Data for the two latter characteristics were not available in most cases, and lack of sufficient data to characterize daily total rainfall and its period of occurrence in terms of its intensity, duration, and infiltration characteristics did not permit such an attempt, although this approach has been utilized by some workers (56).

A soil moisture level between the wilting point, i.e. zero available water and 1.50 inches was characterized as a "deficit," and the difference in soil moisture balance and 1.50 inches was shown as a deficit. The particular day was counted as a "deficit day."

The deficit was allowed to continue, increasing daily to the extent of daily E.T. until such time as enough precipitation was received to raise soil moisture to 1.50 inches or higher. This system served to highlight continued deficit as against occasional deficit. The deficit amount, however, did not represent equivalent irrigation need. The total deficit for a period divided by the number of deficit days represented how much the soil moisture was short of 1.50 inches.

The period after zero balance of soil moisture was reached was termed "drought." It is to be realized that this concept of drought is different from that followed by irrigation workers, and was used to differentiate two levels of moisture shortage. All days of drought were also included in the deficit, due to ease of computation. As the number of drought days were few, no correction was made. Totals of moisture surplus, moisture deficit, and drought were calculated for each month for the quantity in inches and the number of days. The days without surplus, deficit or drought were classed as "days with favorable soil moisture." Total precipitation during the preceding November, December, January and February was also studied for a possible relationship between yield of cane and sugar. The above soil moisture classifications were also grouped in relation to age of the crop viz., early period, growth period and ripening period.

The effect of temperature conditions was studied in the following ways:

(a) Mean monthly temperatures that were found to be significant in preliminary studies, viz., February, March and August through November, were correlated with yield and recoverable sugar.

(b) Day Degrees. This concept involved subtracting the daily maximum temperature from 70 and calculating the positive balances only for the period concerned. It was followed as per Das (25) procedure.

(c) Freeze Damage. The last day of occurrence of a minimum temperature of 32°F or lower in spring was noted each year and the number of days it occurred after January 31 was used as an index of spring freeze conditions. It was expected to be directly related to spring freeze damage. The day of first freeze of 32°F or lower in the fall was also noted and the number of days intervening between September 30 and this occurrence was used as an index for fall freeze conditions. This served as an inverse index of fall freeze.

All the above daily data, except the freeze data, was made available by a program especially written by Mr. Lew D. Harkins of the L.S.U. Computer Center for use on the I.B.M. 1620 Computer and involved the use of two modulations discussed in this study.

Determination of evapo-transpiration

A review of the literature on empirical computational methods for determining E.T., in an effort to find a method that could be used for computing evapo-transpiration, required for this study led to the conclusion that none of them could be wholly reliable. The need to check these computational methods with actual E.T., as determined by the soil moisture balance method or by use of suitable lysimeters was felt necessary before adopting any method for this study. Results of a runoff and water usage by Childs (16) at Crescent Plantation near Houma during 1931-34 were compared with Thornthwaite's P.E. and the data are presented in Figure 4. Soil moisture data at St. James

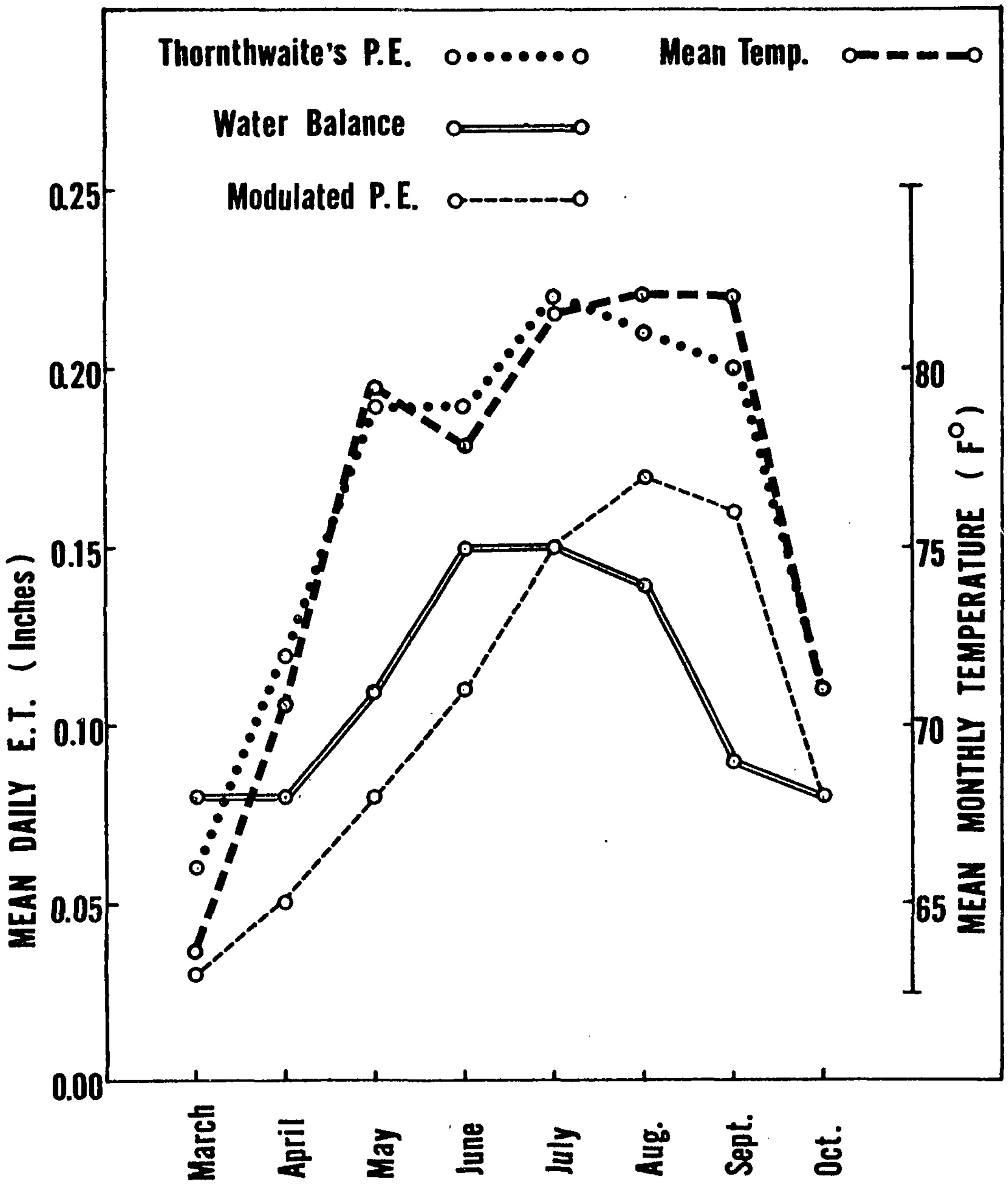


Figure 4. Comparative Mean Daily Water Use by Sugarcane at Houma (La.) for 1933 by 3 Methods & Mean Monthly Temperature.

(Graugnard Plantations) in 1957 and in 1958 in connection with sugarcane irrigation was utilized, along with precipitation data of the plantation. E.T. was calculated from change in soil moisture between the date of sampling and such quantity of precipitation for the intervening period, as could be utilized to pick up the soil-moisture to its peak level of soil-moisture. These results were compared with Thornthwaite's P.E., using temperature data for Reserve.

Soil moisture data for a sugarcane field at the Houma Station to a depth of 18 inches were kindly made available by Mr. L. G. Davidson of U. S. Sugarcane Field Station for the period May 11 to September 2, 1958. In this case also, precipitation data, as recorded by the Houma Station, was treated in relation to the estimated moisture balance for the day to arrive at effective precipitation. Thornwaite's P.E. was calculated in this case also.

In all these three cases, it was noted that Thornthwaite's P.E. was considerably higher than the E.T. calculated from actual data. Thornthwaite's P.E. was particularly higher in the early period of growth. The total E.T. in the above three studies for July, August, and September worked out to about 12 inches, as against about 16-18 inches by Thornthwaite's method.

Soil moisture data for sugarcane at Cinclare Plantation, West Baton Rouge by Saveson and Lund (95) from 3/30 to 9/26/55 was utilized to compare computational methods based on temperature, relative humidity, wind speed and hours of sunshine. The data for hours of sunshine were obtained for New Orleans, while the rest of the data were from Ryan Air Port, Baton Rouge. The methods compared were those of Thornthwaite, Blanney-Criddle, Hargreaves, Holdridge, Albrecht, Ivanov, Haude and Penman. Table 4 gives a comparison of these for Cinclare Plantation in 1955. Considerable variation may be noted. Relationship of E.T. to weather elements is depicted in Figure 5, while a comparison of E.T. by different methods is presented in Figure 6.

Methods based on saturation deficit appeared best, but even in these cases, the need for modulation in the early period was felt. Furthermore, the lack of relative humidity data for the weather stations of the sugarcane area precluded their use in this study.

Modulation due to the lack of complete cover in the early period of the crop was provided on the basis of E.T. determinations for sugarcane in Hawaii by Chang (14). He reported that the ratio $\frac{\text{E.T. in sugarcane}}{\text{Evaporation from tank}}$ was 0.40, 0.45, 0.54 and 0.84 for the first four months of the crop, after it had germinated. Thereafter he reported the ratio to be around 1.0 until ripening, when it fell below 1.0 again. In Louisiana, the crop was harvested when it had lot of green leaves and as such modulation in October was not felt necessary. It was considered necessary to modulate E.T. for different levels of soil moisture between field capacity and wilting point and also for soil moisture below wilting point. A quantitative evaluation of E.T. at wilting point was provided by Carlson (13) and by Larsen (66), who found it to be around 30 per cent of the E.T. at field capacity. Shaw and Sewezy (96) and Sewezy and Shaw (109) reported some data of E.T. for soils after it had reached wilting point. Their data indicated it to be about 20-25 per cent of E.T. at field capacity. The change in E.T. with soil moisture was regarded as linearly related to soil moisture, as per work cited earlier (page 22). In view of

Table 4. Comparison of Computational Methods for E.T. for Sugarcane at Cinclare Plantation, W. Baton Rouge, Parish in 1955, and Mean Weather Data for the Periods.

Particulars	Periods			
	3/30-5/25	5/26-6/19	6/20-8/10	8/11-9/25
A. Weather				
Mean Temperature ° F.	74.0	77.5	81.0	82.4
R.H.D. (Mean Daily)	72.0	70.0	79.0	78.0
R.H.D. At 2 P.M.	49.0	51.0	62.0	62.0
Wind Speed (in m.p.h.)	8.7	7.0	5.5	6.3
Hours of Sunshine (% of Possible)	67.0	76.0	60.0	61.0
B. Method	Daily E.T. in Inches			
1. Thornthwaite P.E.	.147	.186	.222	.212
2. Blaney Criddle	.110	.190	.244	.232
3. Hargreaves	.152	.0179	.184	.204
4. Holdridge	.148	.160	.185	.178
5. Albrecht	.126	.151	.119	.130
6. Ivanov	.154	.178	.135	.146
7. Haude	.143	.170	.162	.148
8. Penman	.157	.179	.151	.140
9. Modulated P.E.	.057	.078	.154	.122
10. Actual as per Soil Moisture Balance Method	.064	.085	.120	.125

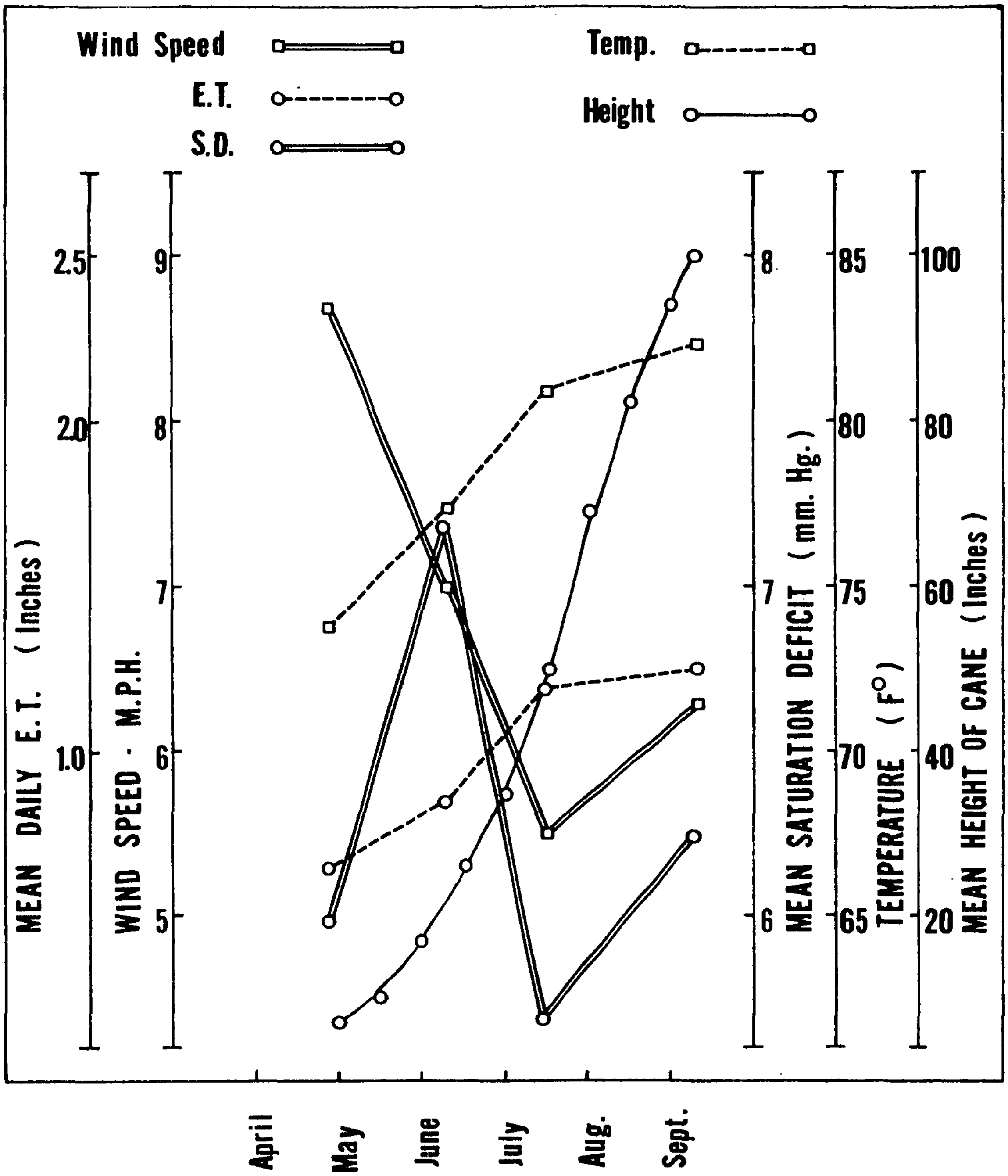


Figure 5. Relation of E.T. for Sugarcane at Cinclare Plantations During 3-30 to 9-26-55 with Mean Air Temp, Wind Speed and Saturation Deficit.

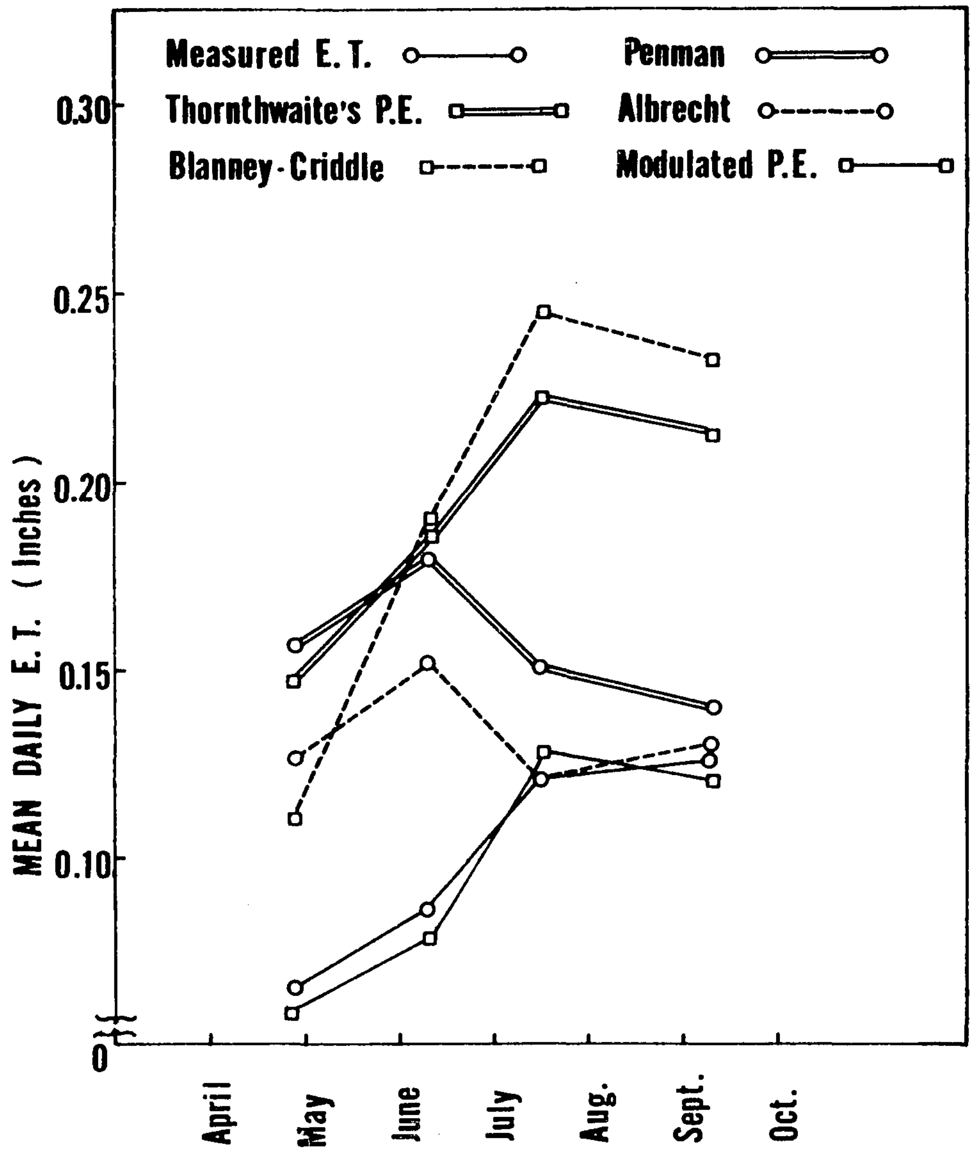


Figure 6. Comparison of Mean Daily Evapotranspiration in Inches at Cinclare Plantation (West Baton Rouge Parish) During 3/30 to 9/25/55 by Different Computational Methods and E. T. as determined by Soil Moisture Method.

the evaporating conditions being milder in Louisiana, E.T. at wilting point was regarded as 32 per cent of the E.T. at field capacity and the following formula was used to complete E.T. at different levels of soil moisture:

$$\text{Corrected E.T.} = \text{Thorthwaite's P.E.} \times (0.17 \times \text{available water in inches} + 0.32)$$

In accordance with the above formula, it took a soil with 4 inches of water-storage capacity 34 days to reach wilting point at a uniform potential evapo-transpiration of 0.20 inches, instead of 20 days, if no modulation was provided.

When Thornthwaite's P.E. was modulated as above and in accordance with vegetation factor after Chang's data (14), it was found to be in fair agreement with E.T., as measured by soil moisture data for Cinclare Plantation in 1955 discussed on page 40. This modulated method was adopted for use in this study. Computations of E.T. were made on I.B.M. 1620 high speed computer, using Thornthwaite's calculated P.E. for the weekly periods on the basis of daily weather data cards. The weekly periods used were 1-7, 8-15, 16-22 and 23 to end of the month for the period March-October. Moisture balances were computed daily on the basis of daily precipitation, and mean daily E.T., calculated as above.

Selection of a period for study

The early period up to 1919 was not considered desirable for the study, as the conditions of cane cultivation in this period differed greatly from present practices. Looking at the yield data over the period 1919-1960, the period may be divided into two sub-periods, 1919-35 and 1936-60. This division was based on the following:

(1) Large variations in yield as explained by Edgerton (35), due, for example, to ill defined diseases, pests and certain other reasons. These variations were especially large up to 1935. The later sub-period, 1936-1960, did not have such serious disease outbreaks.

(2) The varietal census showed a definite change as per data below (Arceneaux, 4).

Table 5. Percentage area occupied by cane varieties in Louisiana.

Variety	1935	1936
Noble Canes	1.6	--
P.O.J. 234	18.9	5.2
P.O.J. 36/367	25.7	4.3
P.O.J. 213	7.7	4.4
	53.9	13.9
Co. 281	21.8	46.7
C.P. 207	11.5	6.1
Co. 290	10.8	16.3
C.P. 28-19	1.2	9.6
C.P. 28-11	0.5	5.9
C.P. 29-320	0.2	1.5
	46.1	86.1

The later period marked the cultivation of C.P. and Co. canes almost exclusively.

With a view to further decide if the entire period 1919-60 could be utilized for the study providing the advantage of a longer period, the correlation of yield with precipitation and temperature for different months for the state as a whole was determined. It was realized that the weather for sugarcane area differed from the state-average, but the two were closely related and the state averages were more easily available. The data are presented in Table 6.

Table 6. Correlation of State Weather Data with Cane Yield for the Two Periods, 1919-35, 1936-59.

Variable	1919-35 Mean Value	1919-35 r	1936-59 Mean Value	1936-59 r
1. Precipitation (Inches) March	5.53	- .153	5.14	-.457*
2. Precipitation (Inches) Feb.-March	10.08	- .161	9.48	-.341
3. Precipitation (Inches) April-October	32.31	.211	33.03	-.218
4. Mean Temp. for March (^{o}F)	60.1	0.657**	59.9	.264
5. Mean Temp. for Feb.-March (^{o}F)	58.0	.645**	57.2	.402
Yield in tons/Acre	13.30		20.00	
Level of Significance for 5% P		.482		.404

The two periods showed very different relationships to precipitation and temperature in the early part of the growing season. However, yields were not significantly influenced by total precipitation during the growing season (April-October) for either the 1919-35 or the 1936-59 periods. Multiple correlation of yield in 1919-35 with precipitation and temperature in March, and precipitation in July-August and April-October, resulted in a coefficient of determination of .638, as compared with 0.221 for corresponding values of the 1936-59 period.

The above was considered enough evidence to use the later period only for further studies.

With a view to further decide the issue, multiple regression of yield was run for the entire period 1919-59 with the weather-elements, treating the two periods as variables. The independent variables studied were the two sub-periods, total precipitation in November, December and January, precipitation in February, March, April through October, and July through September and temperature in March and February. The periods had a t value of 8.16, the level of significance being 2.05 for 5 per cent probability. Out of the rest of the variables studied, only mean temperature for March was significant with a t of 2.505. It was thus concluded that the two periods differed significantly and should not be studied together. Further study was thus limited to the period 1936-60.

RESULTS

To start with, mean cane yield per acre and mean recoverable sugar per ton cane for Louisiana State was studied in their relation to mean monthly precipitation and mean monthly temperature of the sugarcane area. The latter represented the average of 11 weather stations located in the sugarcane area and listed on page 31. The period covered by the study was 1936-60.

Significant association of cane yield with precipitation for March and for June was noted. The correlation coefficient values (r) obtained were -.523 and -.429, respectively. The combined precipitation of March and April was significant at the one per cent level of probability. Sugar per ton cane was negatively correlated significantly with precipitation for November and mean temperature for August, the latter at the one per cent level of probability. Results are given in Table 7.

Mean monthly moisture balances were worked out on the basis of mean monthly temperature and precipitation data of sugarcane area by Thornthwaite's method and relation with cane yield and sugar per ton cane were computed. In addition, the data for fertilizer nitrogen sold in the sugarcane area, and mean percentage joints bored by sugarcane borer were also included in the study. The variables studied and the correlation coefficients are given in Table 8.

High significant negative association was noted between yield and surplus for March through October ($r = .691$). Sugar per ton was

Table 7. Total Correlation Coefficient of Yield of Cane and Sugar Per Ton Cane With Mean Monthly Weather Data of Sugarcane Area, Louisiana for 1936-60.

Period For Weather	Yield of Cane With		Sugar Per Ton Cane With	
	Precipitation	Temperature	Precipitation	Temperature
1. February	.140	.335	.291	-.109
2. March	-.523*	.031	-.308	-.188
3. April	-.242	.131	.139	-.173
4. May	.067	.076	.066	.122
5. June	-.429*	-.050	.189	-.188
6. July	.084	.180	.171	-.133
7. August	-.202	-.165	.116	-.596**
8. September	-.111	.294	-.210	-.075
9. October	.102	-.363	.125	.140
10. November	-.280	-.036	-.408*	-.100
11. November-December-January	-.180	.043	-.321	.056
12. February-April	-.464*		.018	
13. February-March	-.433*	.223	-.076	-.175
14. March-April	-.596**		-.178	
15. April-September	-.337		.174	
16. July-September	-.180		.070	
17. February-May		.199		-.291
18. April-October		.012		.017
19. October-November		-.222		-.004

Table 8. Total Correlation Coefficients of Cane Yield and Sugar Per Ton Cane With Mean Monthly Soil Moisture Status, Temperature Conditions and Other Related Factors.

Independent Variable Particulars	Mean Value	Correlation Coefficient With	
		Yield of Cane	Sugar/Ton Cane
1. Moisture Surplus (Inches)-March-October	8.65	-.691**	-.019
2. Ditto-April-October	5.35	-.502*	+.136
3. Ditto-September	5.00	-.532*	.163
4. Moisture Drought (Inches)-Annual	2.75	-.155	-.386
5. Ditto-June-October	2.75	-.155	-.386
6. Ditto-September	2.28	-.138	-.448*
7. Spring Freeze Days (After March 1)	8.3	-.121	.033
8. Freeze-free Days in Fall (After November 1)	13.1	.137	.092
9. Frost Free Period (Days)	271.5	.058	.060
10. Moisture Surplus (Inches)-November-March (Antecedent)	15.56	-.432*	-.211
11. Ditto-January-March	10.80	-.466*	-.294
12. Ditto-February-March	6.99	-.433*	-.017
13. Ditto-March-April	5.06	-.522*	-.096
14. Ditto-April-May	2.87	-.274	.075
15. Ditto-September	.47	.021	.178
16. Ditto-October	.35	.096	-.132
17. Ditto-November	1.57	-.203	-.500*
18. Moisture Surplus October-November	1.93		
19. Moisture Deficit (Inches)-November	.52	-.120	-.025
20. Fertilizer Nitrogen (1,000 Tons)	10.36	.492*	
21. Percentage joints Bored	16.5	.390	.337
22. Years (Time series effect)	48.0	.424*	

negatively associated with drought over the period June through September ($r = .448$), as also with moisture surplus for November. These results were in line with results reported in Table 7. Fertilizer nitrogen consumed was positively related to the yield of cane, and relation with per cent joints bored just failed to reach the significant level.

Multiple regression analysis was run between cane yield and the following sixteen variables:

A) Precipitation for November through January (antecedent), February, March, June, March-April, August, and November.

B) Mean temperature for February, August, September and October.

C) Moisture surplus in March-October.

D) Moisture deficit for the year, and for June through September.

E) Fertilizer nitrogen used in sugarcane area.

F) Average per cent joints bored.

These variables were correlated with cane yield and sugar per ton of cane to find out what percentage of the variation in cane yield and sugar per ton could be accounted by these. Multiple coefficient of determinations was found to be .895 and .676 for cane yield and sugar per ton cane, respectively, indicating that considerable variation in sugar per ton cane was not explained by the above variables.

With a view to identify the variables primarily affecting the cane yield, multiple regression analysis was run with 6 of the above variables, which yielded a coefficient of determination of .837, about 6 per cent less than obtained with 16 variables. The variables studied along with other data are given below:

Table 9. Multiple Regression Analysis for Cane Yield in Louisiana for 1936-60.

Variable	Standard Partial Regression Coefficient (b)	T	Simple Correlation Coefficient (r)
Moisture Surplus March-Ocrober (in.)	-.1247	5.03**	-.596
Mean Temp. for February (^{o}F)	+.0993	1.54	+.335
Mean Temp. for September	-.1305	.73	+.294
Mean Temp. for November	+.1080	.95	+.036
Fertilizer Nitrogen Used (1000 Tons)	+.0131	4.26*	+.492
Percentage Joints Bored	+.1371	3.38*	+.390
t at 5% Level of P.		2.101	

From the results of this analysis, moisture surplus and fertilizer nitrogen may be regarded as the more important variables associated with sugarcane yields. Multiple regression analysis with only these two variables yielded a multiple coefficient of determination of .7959, and t values of 9.92 and 6.15, respectively, both significant. The regression equation was as under:

$$y = 18.024 - .1548X_1 + .2114X_2$$

when X_1 = moisture surplus in cms., and X_2 = fertilizer nitrogen sold in 1000 tons.

The above study pointed out that these two factors were the most significant in cane yield relations. Relation of actual cane yield and yield estimated from the above regression equation is shown in Figure 7.

<u>Sugarcane yield per acre and recoverable sugar per ton cane in parishes</u>

The results of above correlation studies of mean cane yield and recoverable sugar per ton cane for Louisiana had an inherent weakness, in common with results of all studies based on the mean of a population. The data lacked much of the variation. It was also based on mean monthly weather data of 12 stations with considerable difference in their pattern of rainfall and temperature as given on pages 12-16. The study was thus extended to cover individual sugarcane growing parishes in respect of which weather data for a period not less than 13 years was available. This study of the effect of soil moisture status and temperature conditions was based on daily weather data of the representative weather station of the parish concerned, and thus provided a good basis for studying the effect. The results for each parish studied are given in the following.

A) <u>Assumption Parish</u>. Results of correlation analysis of cane yield per acre and recoverable sugar per ton cane* in the parish along with mean data for the variables and their respective standard deviations over the period 1948-60 are presented in Table 10. Cane yield was negatively associated significantly with moisture surplus for April and surplus days for March-May. It was positively related significantly with day-degrees for April (r = .609), which relation is presented in Figure 8. Recoverable sugar did not have a significant

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*Cane yield per acre in tons has been abbreviated as 'cane yield,' while recoverable sugar per ton of cane as 'sugar per ton' in the following pages.

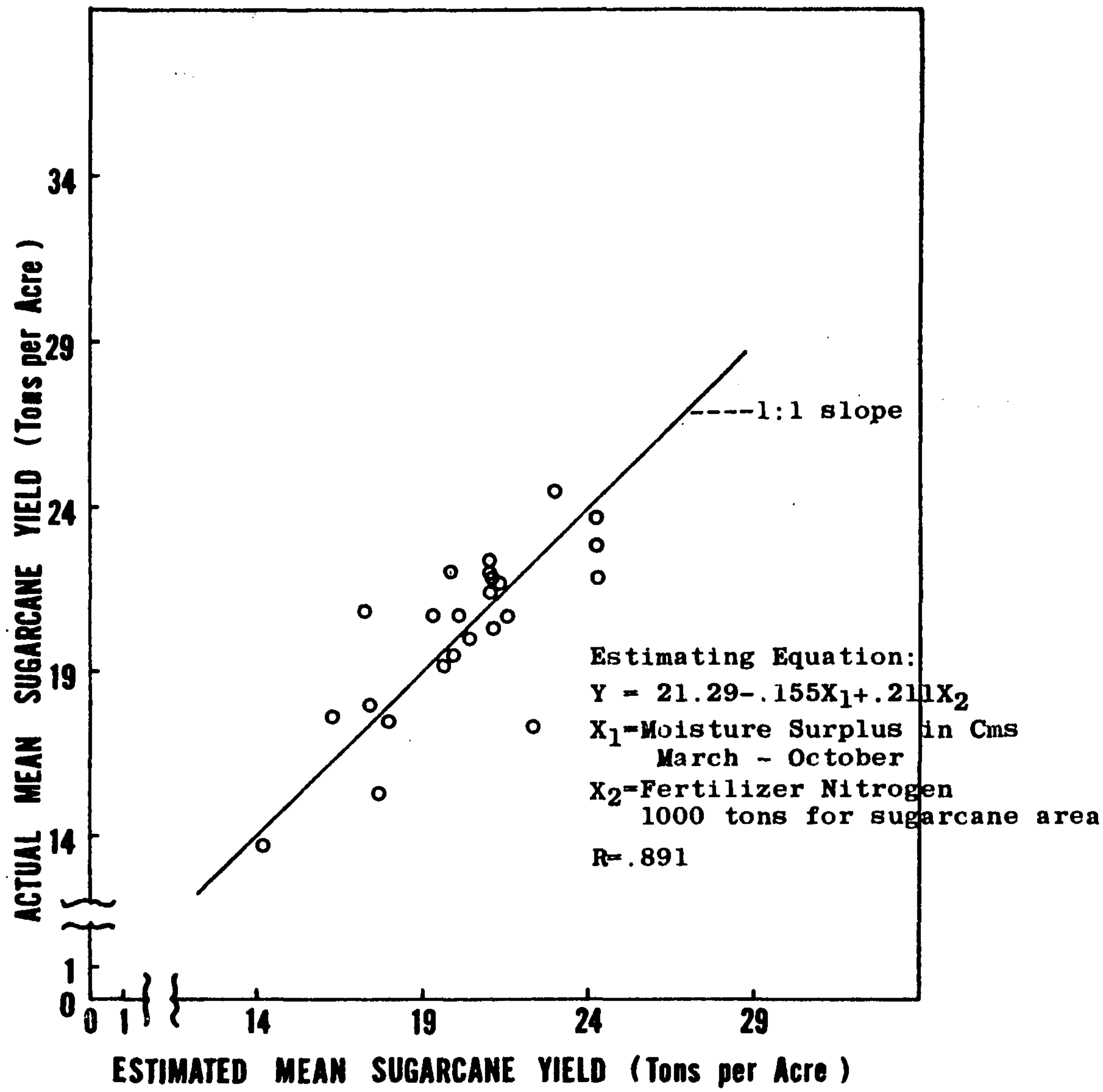

Figure 7. Relation of Actual Mean Sugarcane Yield and Mean Yield Estimated From Soil Moisture Surplus (March-October) and Fertilizer Nitrogen Sales in Sugarcane Area During 1936-60.

Table 10. Correlation Studies of Sugarcane Yield and Sugar Per Ton for Assumption Parish, Louisiana for the Period 1948-60.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
1.	Yield in Tons/Acre	22.46	.27		-.149
2.	Sugar/Ton (Lbs.)	161.0	1.5	-.149	
3.	Moisture Surplus (Inches) - March	5.25	.43	-.417	-.289
4.	Ditto - April	4.01	.29	-.574*	.039
5.	Ditto - May	3.10	.37	-.004	.228
6.	Ditto - June	2.13	.22	-.039	.139
7.	Ditto - July	3.16	.30	.273	.275
8.	Ditto - August	1.72	.18	.145	-.110
9.	Ditto - September	2.61	.33	.013	-.124
10.	Ditto - October	1.27	.17	.333	.271
11.	Ditto - March-October	23.25	.69	-.275	.101
12.	Precipitation for November, December, January, February (Antecedent)	18.70	.21	.225	.055
13.	Precipitation for November (Current)	3.76	.36	.022	-.070
14.	Moisture Surplus Days - March	5.2	.29	-.235	-.194
15.	Moisture Surplus Days - March-May	11.2	.37	-.546	.145
16.	Moisture Surplus Days - September-October	4.6	.39	.213	-.163
17.	Moisture Deficit (Inches) - May-September	3.06	.31	-.045	.271
18.	Ditto - July-September	2.54	.25	.040	.330
19.	Ditto - October	2.88	.89	-.037	.332
20.	Moisture Deficit Days - May-September	10.5	.85	-.022	.300
21.	Moisture Deficit Days - July-September	8.5	.85	.077	.305
22.	Moisture Deficit Days - October	4.2	.89	-.049	.336
27.	Mean Temperature for February	57.9	.45	-.140	-.013
28.	Day Degrees for March	145.0	5.7	.170	-.119

Table 10 . Continued.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Sugar Per Ton
29.	Mean Temperature for March	61.3	.27	.060	-.060
30.	Lowest Weekly Minimum Temperature for April	51.5	.30	.230	.003
31.	Day Degrees for April	280.0	7.1	.609*	-.119
32.	Day Degrees for April-September	3277.0	11.4	.348	-.243
33.	Mean Temperature for August	81.5	.93	-.479	-.360
34.	Ditto - September	77.9	.135	.097	-.035
35.	Ditto - October	69.2	.33	-.271	.336
36.	Ditto - November	59.7	.22	.486	-.241
37.	Number of Days After January 31 to Last Spring Freeze	23.8	1.49	.023	-.099
38.	Number of Days After September 30 to First Fall Freeze	37.2	1.50	.171	-.038
39.	Number of Days with Favorable Soil Moisture	205.0	1.46	.077	-.405

Level of significance for "r" at 5% P. - .553

Level of significance for "r" at 1% P. - .684

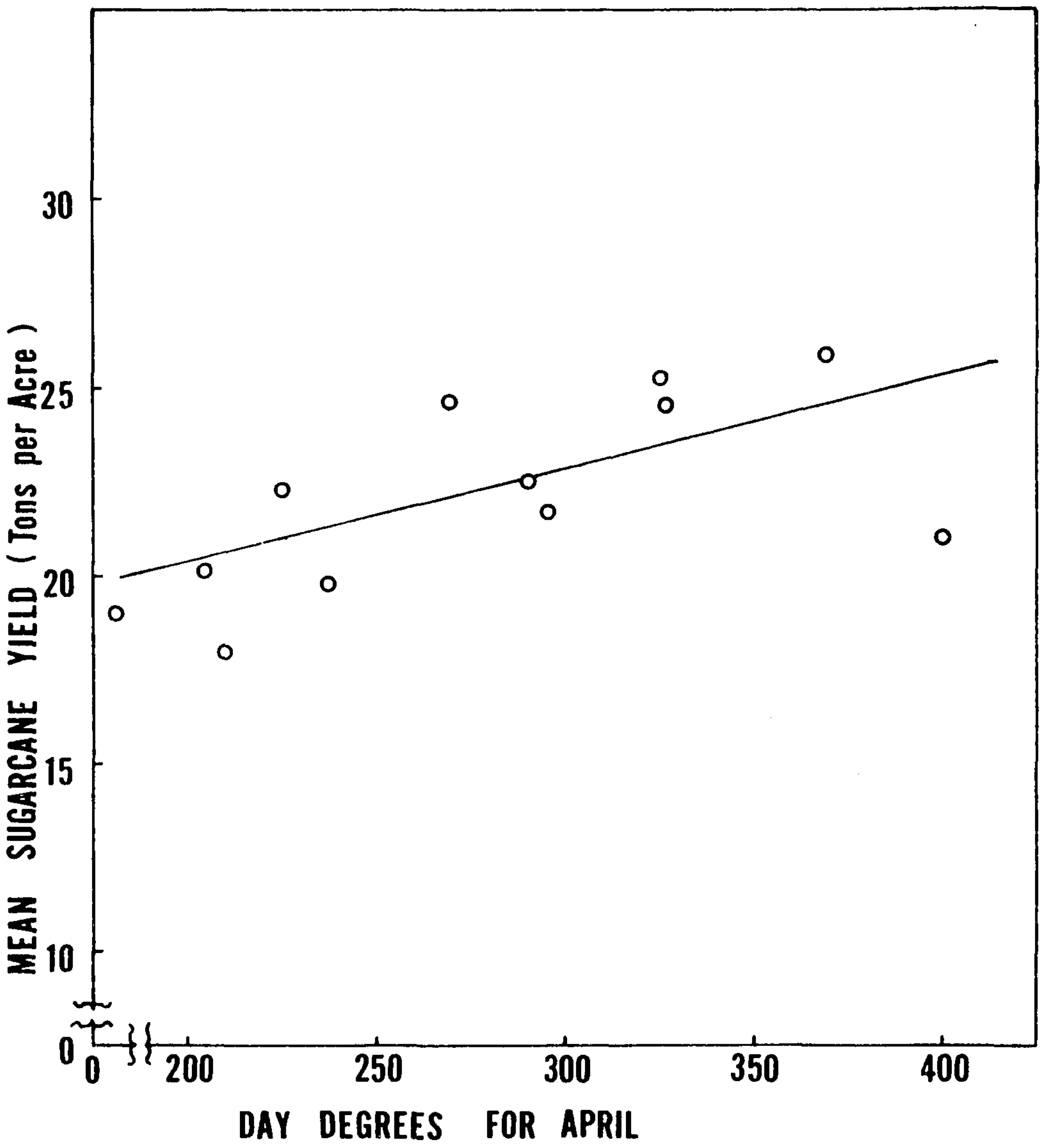

Figure 8. Relation of Mean Sugarcane Yield in Assumption Parish and Mean Day Degrees for April During 1948-1960.

association with any of the variables tested. The parish had no drought, a high moisture surplus and a low moisture deficit in the active growth period (July-September).

B) Iberia Parish. Results of correlation analysis for cane yield per acre and recoverable sugar per ton cane are given in Table 11 and cover the period 1937-60, with omissions of 1939 and 1940. Cane yield was negatively related at one per cent level of probability (r = .613) with moisture surplus in March, which relation is shown in Figure 9. Multiple regression analysis* of cane yield with variables numbers 3, 8, 13, 15, 28, 33 and 35, as per Table 11 was run and gave a multiple coefficient of determination** of .682 and F value of 4.29, significant at five per cent level. Moisture surplus days and August temperature only had significant t values of 2.160 and 2.234, respectively, with standard partial regression coefficients of -.165 and -.823, respectively. It was noted that moisture surplus in March was not significant in M.R. analysis in spite of a high total correlation coefficient. Moisture surplus did not appear to have a significant effect, if temperature conditions were uniform.

Recoverable sugar had a significant negative association with moisture deficit for May-September and August temperature. M.R. analysis was run with variables numbers 17, 20, 32, and 33 yielding an R^2 of .510, and an insignificant F value. Moisture deficient days

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*Abbreviated as M.R. analysis hereafter.

**Abbreviated as R^2 hereafter.

Table 11. Correlation Studies of Sugarcane Yield and Sugar Per Ton for Iberia Parish, Louisiana for the Period 1937-60.[1]

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
1.	Yield in Tons/Acre	18.95	.19		.245
2.	Sugar/Ton (Lbs.)	166.3	.95	.245	
3.	Moisture Surplus (Inches) - March	4.40	.32	-.614**	-.138
4.	Ditto - April	2.96	.19	-.206	.121
5.	Ditto - May	2.63	.23	-.262	.199
6.	Ditto - June	2.16	.26	-.296	.218
7.	Ditto - July	3.01	.39	-.230	-.147
8.	Ditto - August	1.40	.24	.391	.199
9.	Ditto - September	1.32	.29	.019	.103
10.	Ditto - October	.95	.20	.093	-.187
11.	Ditto - March-October	18.82	.80	-.429*	.081
12.	Precipitation for November, December, January, February (Antecedent)	17.88	.44	-.059	-.221
13.	Precipitation for November (Current)	3.88	.30	-.316	-.047
14.	Moisture Surplus Days - March	5.4	.27	-.278	.031
15.	Moisture Surplus Days March-May	12.4	.47	-.548**	.233
16.	Moisture Surplus Days - September-October	2.6	.25	.046	-.201
17.	Moisture Deficit (Inches) - May-September	6.46	.66	-.286	-.515*
18.	Ditto - July-September	5.30	.492	-.209	-.240
19.	Ditto - October	5.11	1.08	.159	.258
20.	Moisture Deficit Days - May-September	16.2	1.31	-.272	-.400
21.	Moisture Deficit Days - July-September	13.3	.95	-.240	-.206
22.	Moisture Deficit Days - October	6.5	1.19	.150	.339
27.	Mean Temperature for February	55.6	.44	.254	-.205

Table 11. Continued.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
28.	Day Degrees for March	118.0	6.2	.354	-.226
29.	Mean Temperature for March	60.4	.39	.248	-.179
30.	Lowest Weekly Minimum Temperature for April	49.2	1.14	.317	-.041
31.	Day Degrees for April	261.0	5.7	.091	-.154
32.	Day Degrees for April-September	3004.0	22.0	.094	-.300
33.	Mean Temperature for August	81.5	.09	-.414	-.500*
34.	Ditto - September	77.6	.16	-.025	-.048
35.	Ditto - October	69.1	.35	-.363	.127
36.	Ditto - November	58.6	.30	.133	.149
37.	Number of Days After January 31 to Last Spring Freeze	22.5	1.7	-.006	-.125
38.	Number of Days After September 30 to First Fall Freeze	48.2	1.4	-.134	.083
39.	Number of Days with Favorable Soil Moisture	200.0	1.8	.244	-.076

Level of significance for "r" at 5% P. - .423

Level of significance for "r" at 1% P. - .537

[1]Excepting 1939 and 1940.

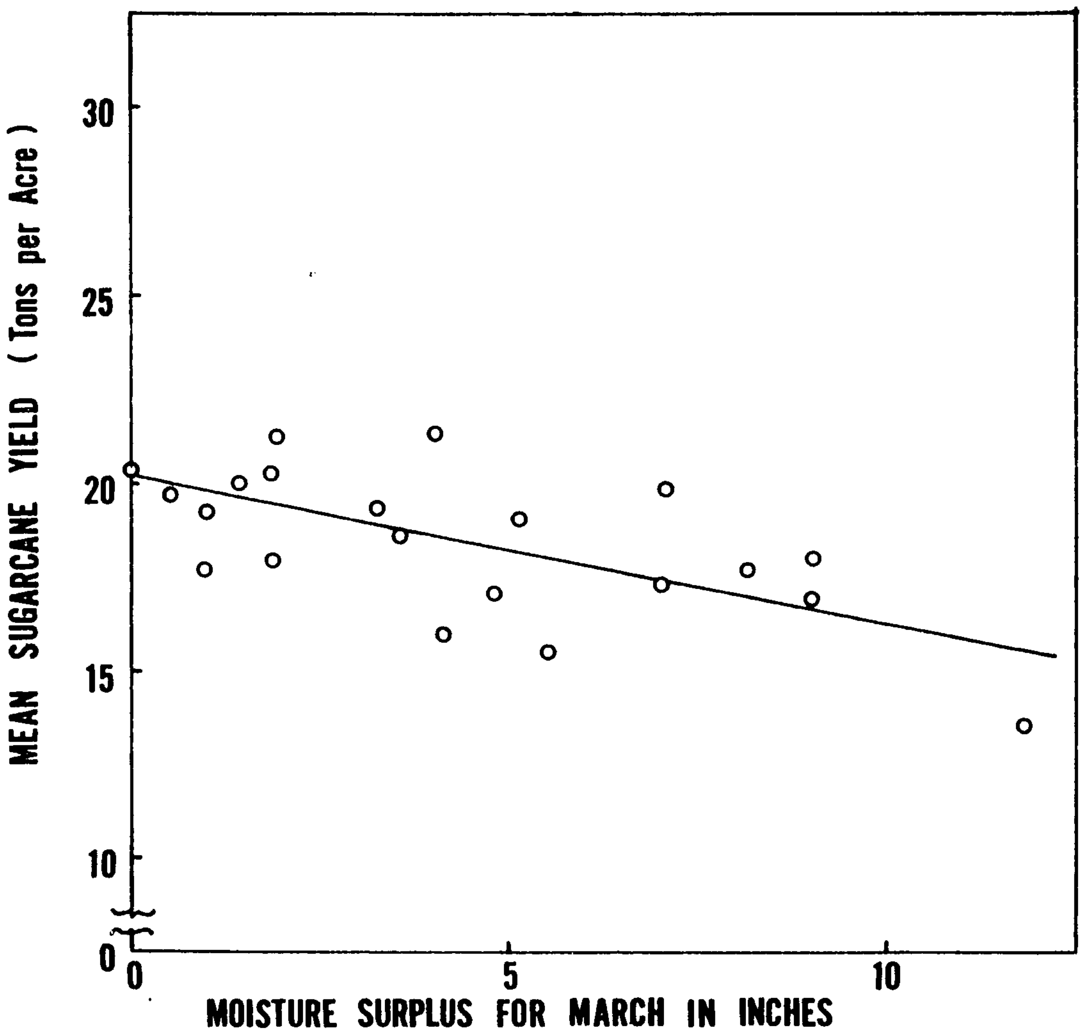

Figure 9. Relation of Mean Sugarcane Yield in Iberia Parish and Moisture Surplus for March During 1937-1960.

only had a significant t value of 2.448 and a standard partial regression coefficient of -.680. Low moisture conditions in May-September did not appear to be favorable for sugar per ton cane.

Iberia Parish had a fairly high moisture surplus, a low moisture deficit and no drought.

C) Lafayette Parish. Results for the period 1937-60 are given in Table 12. Cane yield had a significant negative association with precipitation for November and with moisture deficit for July-September. February temperature and day degrees for April-September were positively associated significantly with cane yield. Relation of cane yield and mean February temperature is shown in Figure 10. M.R. analysis of yield with the above 4 variables, numbers 8, 35, 39, and 27, had an R^2 of .678, a significant F value of 3.89 with none of the variables giving a significant t value.

Lafayette Parish had a fair total moisture surplus, only a moderate moisture deficit and only a small mean drought, yet all the correlation studies suggested existence of droughty conditions and need for more water. Lafayette had the lowest mean cane yield (16.40 tons) among all the parishes studied.

D) Pointe Coupee Parish. Results of correlation analysis for cane yield and sugar per ton cane for the period 1937-60, excepting the years 1941 through 1947, are presented in Table 13. The period of study was 17 years. Cane yield was negatively associated significantly with moisture surplus in August, a rather unusual time for surplus of moisture to have a negative association.

Recoverable sugar was positively related significantly with moisture-surplus days for March-May and with drought days in October.

Table 12. Correlation Studies of Sugarcane Yield and Sugar Per Ton for Lafayette Parish, Louisiana for the Period 1937-60.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
1.	Yield in Tons/Acre	16.40	.30		-.350
2.	Sugar/Ton (Lbs.)	164.5	1.3	-.350	
3.	Moisture Surplus (Inches) - March	4.10	.25	-.358	.249
4.	Ditto - April	3.83	.28	-.019	.260
5.	Ditto - May	2.76	.28	.118	.227
6.	Ditto - June	1.55	.23	-.241	.462*
7.	Ditto - July	1.33	.18	.104	-.123
8.	Ditto - August	2.63	.70	-.354	.181
9.	Ditto - September	.68	.14	-.138	.033
10.	Ditto - October	.82	.20	.057	-.064
11.	Ditto - March-October	17.50	.98	-.389	.417
12.	Precipitation for November, December, January, February (Antecedent)	17.91	.45	.061	.072
13.	Precipitation for November (Current)	3.77	.34	-.445*	.238
14.	Moisture Surplus Days - March	6.2	.29	-.324	.112
15.	Moisture Surplus Days - March-May	13.2	.43	-.245	.555*
16.	Moisture Surplus Days - September-October	2.0	.29	-.083	-.193
17.	Moisture Deficit (Inches) - May-September	13.58	1.1	-.315	.145
18.	Ditto - July-September	11.39	.97	-.424	.143
19.	Ditto - October	7.39	1.29	-.094	.354
20.	Moisture Deficit Days - May-September	28.1	1.51	-.273	-.037
21.	Moisture Deficit Days - July-September	22.5	1.36	-.376	-.055
22.	Moisture Deficit Days - October	9.8	1.24	-.082	.153
23.	Drought (Inches)-June-September	.14	.03	-.064	.304
24.	Drought (Inches) - October	.06	.02	.040	.245

Table 12 . Continued.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
25.	Drought Days - June-September	1.2	.3	-.076	.334
26.	Drought Days - October	.7	.2	.0013	.263
27.	Mean Temperature for February	55.9	.43	.478*	-.191
28.	Day Degrees for March	145.0	8.1	.317	-.294
29.	Mean Temperature for March	60.5	.40	.267	.047
30.	Lowest Weekly Minimum Temperature for April	50.9	.32	.030	.165
31.	Day Degrees for April	281.0	5.6	.149	-.141
32.	Day Degrees for April-September	3319.0	19.1	.438*	-.626**
33.	Mean Temperature for August	81.9	.11	.129	-.541*
34.	Ditto - September	75.1	1.29	.231	-.292
35.	Ditto - October	69.4	.27	-.360	.110
36.	Ditto - November	58.7	.23	-.151	.258
37.	Number of Days After January 31 to Last Spring Freeze	28.2	1.9	-.316	-.355
38.	Number of Days After September 30 to First Fall Freeze	49.9	1.8	-.087	.104
39.	Number of Days With Favorable Soil Moisture	184.0	2.3	.386	-.254

Level of significance for "r" at 5% P. - .404

Level of significance for "r" at 1% P. - .515

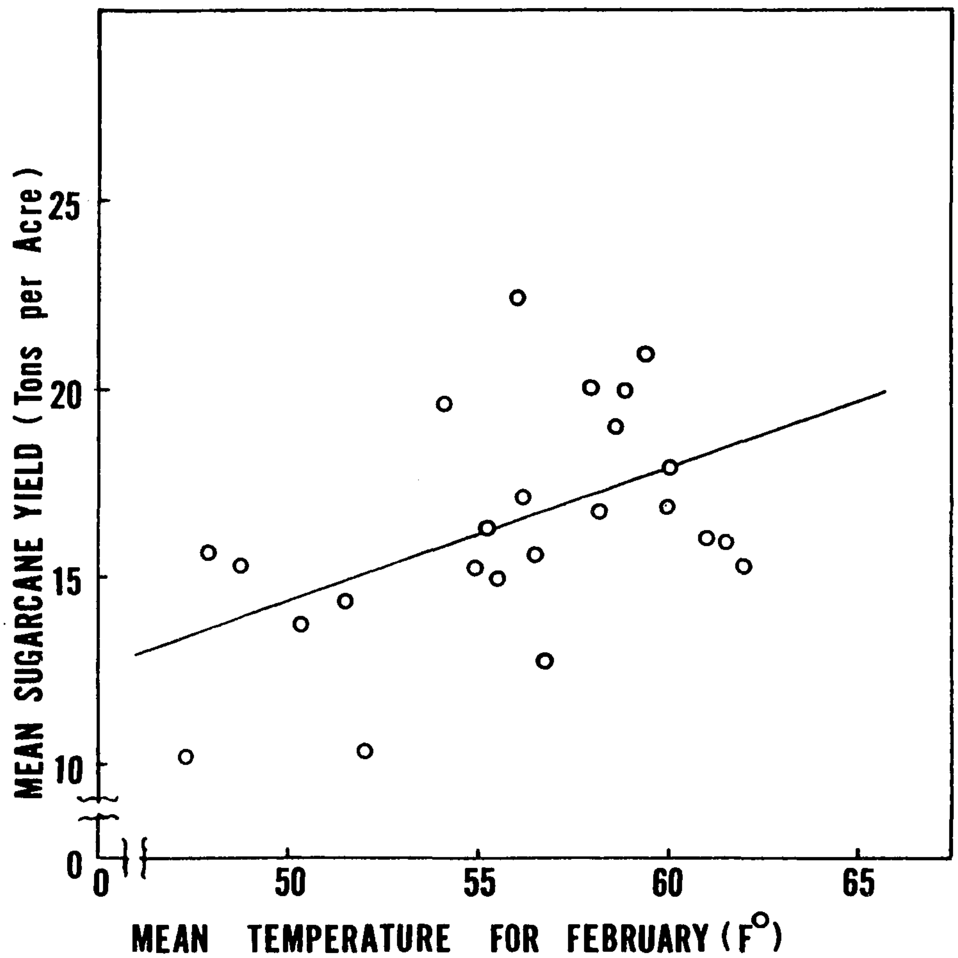

Figure 10. Relation of Mean Sugarcane Yield in Lafayette Parish and Mean Daily Temperature of February During 1937-1960.

Table 13. Correlation Studies of Sugarcane Yield and Sugar Per Ton for Pointe Coupee Parish, Louisiana for the Period 1937-60.[1]

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
1.	Yield in Tons/Acre	20.39	.251		.028
2.	Sugar/Ton (Lbs.)	159.9	.77	-.028	
3.	Moisture Surplus (Inches) - March	3.99	.31	-.233	.171
4.	Ditto - April	4.02	.28	-.074	-.075
5.	Ditto - May	3.55	.65	.147	.382
6.	Ditto - June	1.54	.23	.132	.227
7.	Ditto - July	.48	.09	-.172	-.091
8.	Ditto - August	1.11	.31	-.534*	.086
9.	Ditto - September	.46	.09	.103	-.390
10.	Ditto - October	.72	.15	.048	.179
11.	Ditto - March-October	15.88	.82	-.158	.420
12.	Precipitation for November, December, January, February (Antecedent)	19.76	.55	.154	.191
13.	Precipitation for November (Current)	3.85	.27	-.160	-.289
14.	Moisture Surplus Days - March	6.9	.3	-.099	.421
15.	Moisture Surplus Days - March-May	14.6	.5	-.110	.517*
16.	Moisture Surplus Days - September-October	1.8	.3	.039	-.477
17.	Moisture Deficit (Inches) - May-September	22.23	1.94	-.216	.167
18.	Ditto - July-September	19.74	1.76	-.255	.202
19.	Ditto - October	10.77	1.56	.354	.307
20.	Moisture Deficit Days - May-September	37.8	2.38	-.165	.110
21.	Moisture Deficit Days - July-September	31.9	1.95	-.256	.176
22.	Moisture Deficit Days - October	13.1	1.42	.403	.367
23.	Drought (Inches) - June-September	.20	.05	.209	.008
24.	Drought (Inches) - October	.63	.15	.003	.413

Table 13 . Continued.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
25.	Drought Days - June-September	1.5	.33	.110	.012
26.	Drought Days - October	2.4	.55	-.026	.496*
27.	Mean Temperature for February	56.2	.402	.114	.015
28.	Day Degrees for March	133.0	5.4	.142	-.148
29.	Mean Temperature for March	60.8	.36	.033	-.046
30.	Lowest Weekly Minimum Temperature for April	50.0	.33	.368	-.072
31.	Day Degrees for April	268.1	6.0	.362	-.199
32.	Day Degrees for April-September	3208.0	17.6	.005	-.220
33.	Mean Temperature for August	81.4	.12	-.227	-.465
34.	Ditto - September	76.9	.16	.278	-.091
35.	Ditto - October	68.1	.28	-.056	.100
36.	Ditto - November	54.8	.14	.137	.033
37.	Number of Days After January 31 to Last Spring Freeze	31.0	2.12	-.339	-.376
38.	Number of Days After September 30 to First Fall Freeze	41.7	1.40	-.046	.141
39.	Number of Days with Favorable Soil Moisture	170.0	3.53	-.031	-.350

[1]Excepting 1941-1947.

Level of significance for "r" at 5% P. - .482

Level of significance for "r" at 1% P. - .606

This trend was observed in other parishes also. Pointe Coupee had relatively low mean total surplus moisture, a rather high deficit and even a short mean drought period.

E) Rapides and Avoyelles Parishes. The average data (not weighted) of these two parishes was studied in relation to weather data at Cheneyville up to 1956 and thereafter at Bunkie. Results of correlational analysis for the period 1937-1960 are given in Table 14. Mean daily temperature for August had a significant negative correlation with cane yield. M.R. analysis for cane yield with August temperature and variables numbers 6, 13, 18, 23, 37 and 39 gave an R^2 of 0.588 and the following regression equation:

$$y = 48.32 - .230X_6 - .105X_{13} + .078\ X_{18} + .149X_{23} - .454X_{33} - 0.47X_{37} + .053X_{39}.$$

Days with favorable moisture (variable 39) had a significant t value of 2.37 while spring freeze index (variable 37) had a t value of 2.086 compared to 2.110, the level required for significance at five per cent probability. It was noted that there was considerable interaction which led to the suggestion that conclusions from simple correlational analysis might be questioned.

Recoverable sugar per ton cane was highly correlated with moisture surplus days for March-May. Figure 11 shows this relationship. Mean October temperature was also positively significantly related. M.R. analysis for recoverable sugar with variable numbers 3, 9, 15, 16, and 35 gave an R^2 of only .410. This indicated that other variables had influenced sugar per ton. None of the variables had a significant t value.

Rapides and Avoyelles Parishes represent the northernmost

Table 14. Correlation Studies of Sugarcane Yield and Sugar Per Ton for Rapides and Avoyelles Parishes, Louisiana for the Period 1937-60.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
1.	Yield in Tons/Acre	19.89	.23		.038
2.	Sugar/Ton (Lbs.)	161.5	1.09	-.038	
3.	Moisture Surplus (Inches) - March	4.55	.23	-.113	.344
4.	Ditto - April	4.30	.29	.009	.066
5.	Ditto - May	4.21	.61	-.076	.225
6.	Ditto - June	1.49	.17	-.339	.088
7.	Ditto - July	1.15	.16	.060	-.186
8.	Ditto - August	.79	.14	-.138	.021
9.	Ditto - September	.68	.13	-.184	-.323
10.	Ditto - October	1.05	.18	-.087	-.262
11.	Ditto - March-October	18.23	.82	-.217	.164
12.	Precipitation for November, December, January, February (Antecedent)	19.38	.44	.076	.248
13.	Precipitation for November (Current)	4.95	.41	-.333	-.196
14.	Moisture Surplus Days - March	6.0	.25	-.029	.314
15.	Moisture Surplus Days - March-May	13.7	.43	-.041	.519
16.	Moisture Surplus Days - September-October	1.5	.20	-.244	-.351
17.	Moisture Deficit (Inches) May-September	29.68	3.76	-.324	.032
18.	Ditto - July-September	24.41	3.15	-.322	.184
19.	Ditto - October	3.89	.731	-.087	.198
20.	Moisture Deficit Days - May-September	38.0	3.00	-.273	-.084
21.	Moisture Deficit Days - July-September	31.0	2.12	-.320	.101
22.	Moisture Deficit Days - October	6.8	1.03	-.080	.177
23.	Drought (Inches) - June-September	1.99	.83	-.340	.271
24.	Drought (Inches) - October			-.116	.163

Table 14. Continued.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
25.	Drought Days - June-September	3.8	.10	-.279	.157
26.	Drought Days - October			-.116	.172
27.	Mean Temperature for February	54.1	.437	.100	-.099
28.	Day Degrees for March	132.6	7.0	.021	-.130
29.	Mean Temperature for March	59.97	.42	.020	-.050
30.	Lowest Weekly Minimum Temperature for April	49.9	.29	.130	.258
31.	Day Degrees for April	271.0	6.7	-.108	.025
32.	Day Degrees for April-September	3356.0	.27	-.137	.104
33.	Mean Temperature for August	82.0	.14	-.476*	.052
34.	Ditto - September	77.1	.19	.146	.105
35.	Ditto - October	68.3	.29	-.161	.418
36.	Ditto - November	57.5	.27	.101	-.013
37.	Number of Days After January 31 to Last Spring Freeze	32.7	1.85	-.330	-.187
38.	Number of Days After September 30 to First Fall Freeze	44.3	1.22	.195	.138
39.	Number of Days with Favorable Soil Moisture	177.0	3.7	.389	-.060
40.	Total E.T. in Inches (March-October)	23.18	.36	.253	.113

Level of significance for "r" at 5% P. - .404

Level of significance for "r" at 1% P. - .515

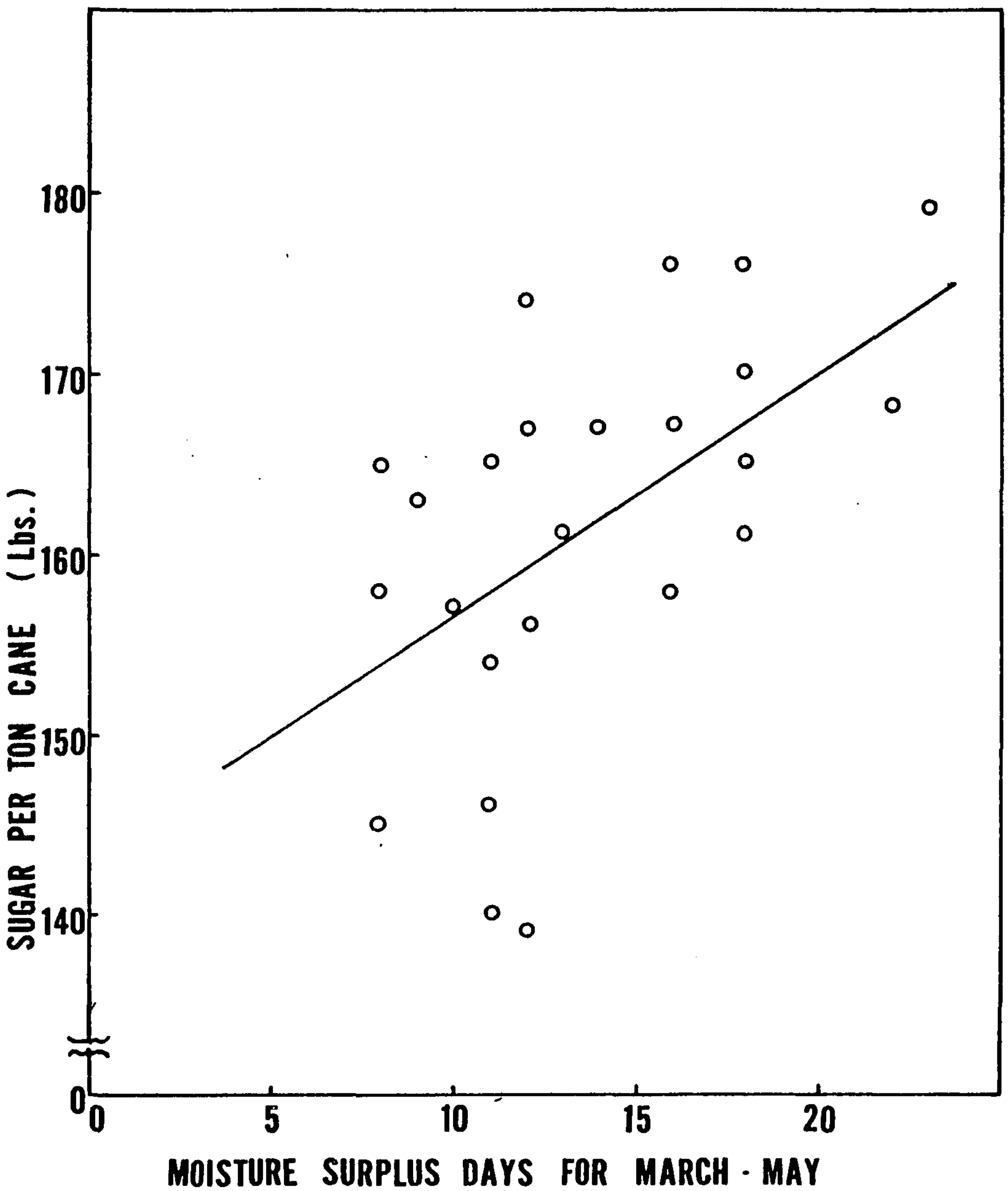

Figure 11. Relation of Mean Recoverable Sugar Per Ton Cane in Pounds and Soil Moisture Surplus Days for March-May During 1936-60. For Rapides and Avoyelles Parishes

parishes growing sugarcane for sugar manufacture. These had a moderate moisture surplus, marked moisture deficit and maximum of drought among the parishes studied. It was noted that M.R. analysis for cane yield indicated the effects of both spring freeze and days with favorable soil moisture.

F) St. Charles, St. James and St. John the Baptist Parishes: These 3 contiguous parishes, represented by a weather station at Reserve, were studied on the basis of their arithmetical mean of cane yield and sugar per ton cane for the period 1937-60. The results of correlation studies are given in Table 15. Cane yield was negatively related with moisture surplus in March and the relation is shown in Figure 12. Moisture surplus in June and fall freeze index had a positive significant association. M.R. analysis was run with variables number 3, 10, 15, 17, 27, 28, 31 and 35, and gave an R^2 of only .528, with none of the variables having a significant t value. It was concluded that there were some other important factors influencing yield in these parishes. Moisture surplus in March had the largest t value, 1.68, and a standard partial regression coefficient of -.380.

Recoverable sugar per ton of cane was related inversely with August temperature, (r = -5.17). M.R. analysis was run with August temperature, variable numbers 33, and variables numbers 6, 7, 20, 29, 37 and 38. The R^2 was .588. August temperature had a significant t value of 2.368. Fall freeze index had a t value of 2.025, but did not reach the significance level of 2.110. Standard partial regression coefficient for August temperature was -3.326, a high value. The regression equation was as follows:

$$y = 429.4 + .871X_6 + .664X_7 + .071X_{20} - .274X_{29} - 3.326X_{33} + .0003X_{37} + .158X_{38},$$

Table 15 . Correlation Studies of Sugarcane Yield and Sugar Per Ton for St. Charles, St. James and St. John Parishes, Louisiana for the Period 1937-60.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
1.	Yield in Tons/Acre	19.87	.307		.118
2.	Sugar/Ton (Lbs.)	166.0	.84	.118	
3	Moisture Surplus (Inches) - March	5.20	.35	-.455*	.044
4.	Ditto - April	3.83	.24	-.009	-.124
5.	Ditto - May	2.39	.25	-.037	.253
6.	Ditto - June	1.87	.23	-.274	.425*
7.	Ditto - July	1.55	.19	-.090	.355
8.	Ditto - August	1.28	.22	-.077	-.239
9.	Ditto - September	1.66	.28	.101	.026
10.	Ditto - October	.87	.20	-.232	-.087
11.	Ditto - March-October	18.58	.71	-.395	.208
12.	Precipitation for November, December, January, February (Antecedent)	19.24	.49	-.011	.064
13.	Precipitation for November (Current)	3.82	.32	-.041	.101
14.	Moisture Surplus Days - March	6.5	.30	-.311	.258
15.	Moisture Surplus Days - March-May	14.5	.49	-.317	.291
16.	Moisture Surplus Days - September-October	2.9	.38	-.046	-.057
17.	Moisture Deficit (Inches) - May-September	17.06	1.81	.384	-.291
18.	Ditto - July-September	14.49	1.72	.190	-.220
19.	Ditto - October	5.23	1.04	.204	.114
20.	Moisture Deficit Days - May-September	26.0	2.04	.317	.344
21.	Moisture Deficit Days - July-September	20.6	1.87	.113	-.252
22.	Moisture Deficit Days - October	8.2	1.19	.237	.121
23.	Drought (Inches) - June-September	.43	.11	.244	-.189
24.	Drought (Inches) - October	.16	.08	.096	.088

Table 15 . Continued.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
25.	Drought Days - June-September	1.8	.4	.295	-.279
26.	Drought Days - October	1.0	.5	.096	.089
27.	Mean Temperature for February	55.5	.46	.323	-.165
28.	Day Degrees for March	127.0	7.1	.347	-.340
29.	Mean Temperature for March	60.4	.39	.219	-.271
30.	Lowest Weekly Minimum Temperature for April	51.8	.29	.008	-.081
31.	Day Degrees for April	255.0	5.6	.368	-.120
32.	Day Degrees for April-September	3209.0	17.8	.265	-.349
33.	Mean Temperature for August	82.5	.12	.068	-.517**
34.	Ditto - September	78.4	.17	.268	-.092
35.	Ditto - October	70.1	.29	-.306	.182
36.	Ditto - November	59.6	.28	-.031	.219
37.	Number of Days After January 31 to Last Spring Freeze	15.7	1.7	.105	-.303
38.	Number of Days After September 30 to First Fall Freeze	65.6	2.0	-.152	.458*
39.	Number of Days with Favorable Soil Moisture	183.4	2.4	-.339	.134

Level of significance for "r" at 5% P. - .404

Level of significance for "r" at 1% P. - .515

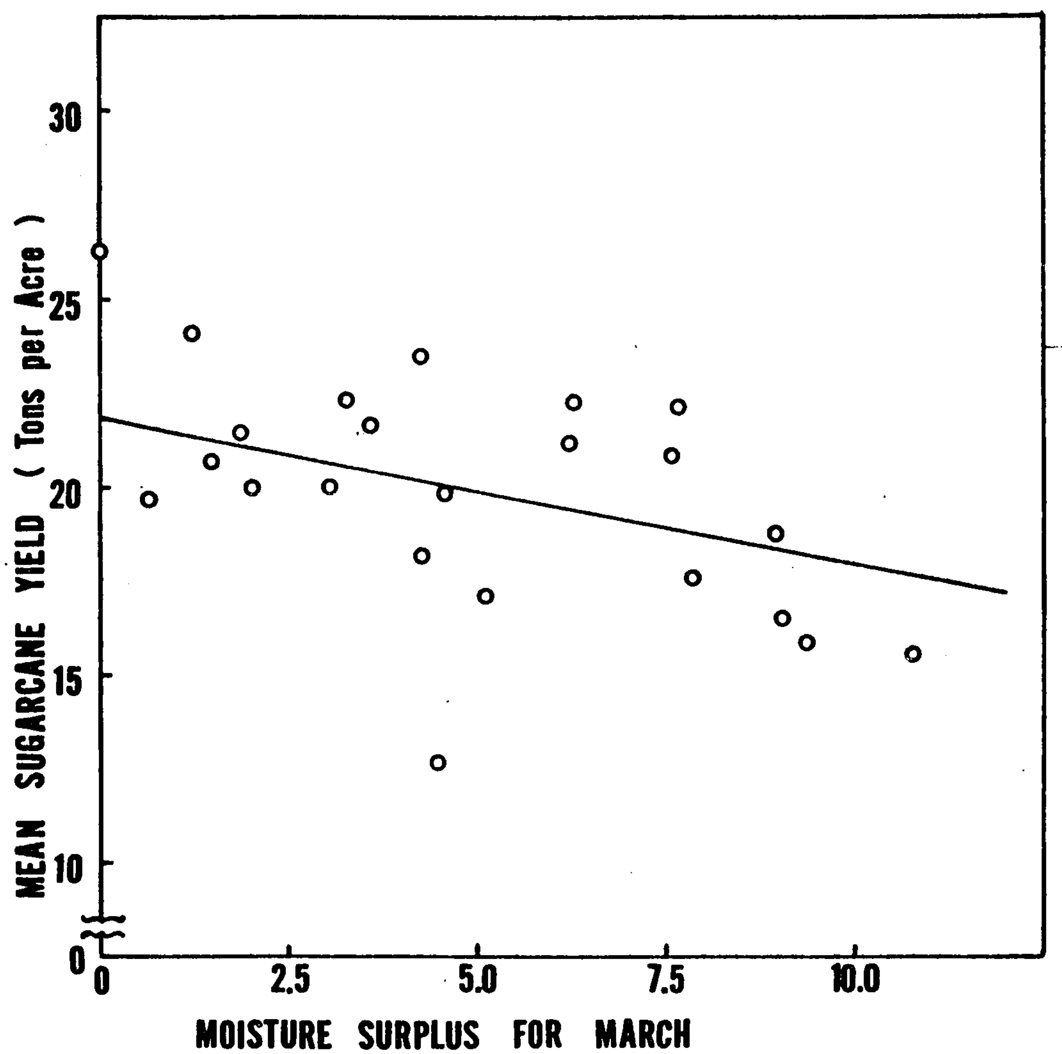

Figure 12. Relation of Mean Sugarcane Yield of St. Charles, St. James and St. John Parishes and Moisture Surplus for March During 1937-60

where y = estimated recoverable sugar per ton of cane in pounds and the other variables are as per Table 15. These three parishes had a fairly high mean total moisture surplus and only a moderate deficit. They appeared to be influenced by fall freeze, but not by the spring freeze.

G) St. Mary Parish: Results of the correlation study over the period 1937-60, excepting 1955 and 1957, are given in Table 16. Cane yield was inversely related with moisture surplus for March, April and June and the precipitation for November and moisture deficit for October. All were significant at five per cent level of probability, except April surplus which was significant at one per cent level. Fertilizer nitrogen did not have significant relation with yield and examination of the data revealed serious discrepancy. It was concluded that tagged sales of fertilizer reported for each parish by dealers did not always represent consumption of all the fertilizer involved in that parish. M.R. with variables numbers 3, 4, 6, 13, 15, 19 and 36 gave an R^2 of .722 and t values of 2.228 and 2.534 for April surplus, and moisture deficit in October, respectively. The regression equation was as follows:

$$y = 20.60 - .181X_3 - .561X_4 - .047X_6 - .199X_{13} - .029X_{15} - .821X_{19} + .023X_{36}.$$

In addition to the above significant variables, surplus moisture in March, and precipitation in November, were also regarded as important in the above analysis. Relation with surplus in April is shown in Figure 13.

Recoverable sugar and mean temperature for August (r = .422) just failed to reach the level of significance. M.R. analysis was run

Table 16. Correlation Studies of Sugarcane Yield and Sugar Per Ton for St. Mary Parish, Louisiana for the Period 1937-60.[1]

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
1.	Yield in Tons/Acre	19.38	.23		.283
2.	Sugar/Ton (Lbs.)	172.0	1.2	.283	
3.	Moisture Surplus (Inches) - March	3.94	.30	-.448*	-.395
4.	Ditto - April	2.65	.16	-.616**	-.257
5.	Ditto - May	2.82	.30	-.035	.320
6.	Ditto - June	2.01	.26	-.458*	.039
7.	Ditto - July	3.01	.30	-.116	-.235
8.	Ditto - August	2.34	.31	-.076	-.011
9.	Ditto - September	2.33	.49	.077	-.085
10.	Ditto - October	.68	.10	.051	-.039
11.	Ditto - March-October	19.80	1.0	-.383	-.175
12.	Precipitation for November, December, January, February (Antecedent)	18.34	.53	-.186	-.321
13.	Precipitation for November (Current)	4.40	.36	-.447*	-.070
14.	Moisture Surplus Days - March	6.1	.33	-.249	-.303
15.	Moisture Surplus Days - March-May	13.1	.51	-.407*	.052
16.	Moisture Surplus Days - September-October	3.0	.30	.099	-.251
17.	Moisture Deficit (Inches) - May-September	5.78	.79	-.039	-.304
18.	Ditto - July-September	3.64	.54	.022	-.148
19.	Ditto - October	.42	.12	-.463*	-.211
20.	Moisture Deficit Days - May-September	13.3	1.35	-.027	-.332
21.	Moisture Deficit Days - July-September	9.1	1.05	.060	-.184
22.	Moisture Deficit Days - October	3.3	.65	.0036	.114
27.	Mean Temperature for February	57.3	.45	.372	-.018

Table 16. Continued.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
28.	Day Degrees for March	13.6	.16	.065	-.060
29.	Mean Temperature for March	61.9	.40	.119	-.071
30.	Lowest Weekly Minimum Temperature for April	49.8	1.15	.065	.187
31.	Day Degrees for April	273.0	8.1	-.110	-.206
32.	Day Degrees for April-September	3138.0	27.0	-.303	-.303
33.	Mean Temperature for August	82.0	.12	-.102	-.422
34.	Ditto - September	78.5	.15	-.046	.119
35.	Ditto - October	70.3	.35	-.260	.007
36.	Ditto - November	60.5	.25	-.364	-.156
37.	Number of Days After January 31 to Last Spring Freeze	15.6	1.5	-.094	-.190
38.	Number of Days After September 30 to First Fall Freeze	65.7	2.2	-.214	.276
39.	Number of Days with Favorable Soil Moisture	202.0	1.5	-.194	.167
40.	Fertilizer Nitrogen (Lbs./Acre)	46.5	2.2	.164	.122

[1]Excepting 1955 and 1957.

Level of significance for "r" at 5% P. - .423

Level of significance for "r" at 1% P. - .537

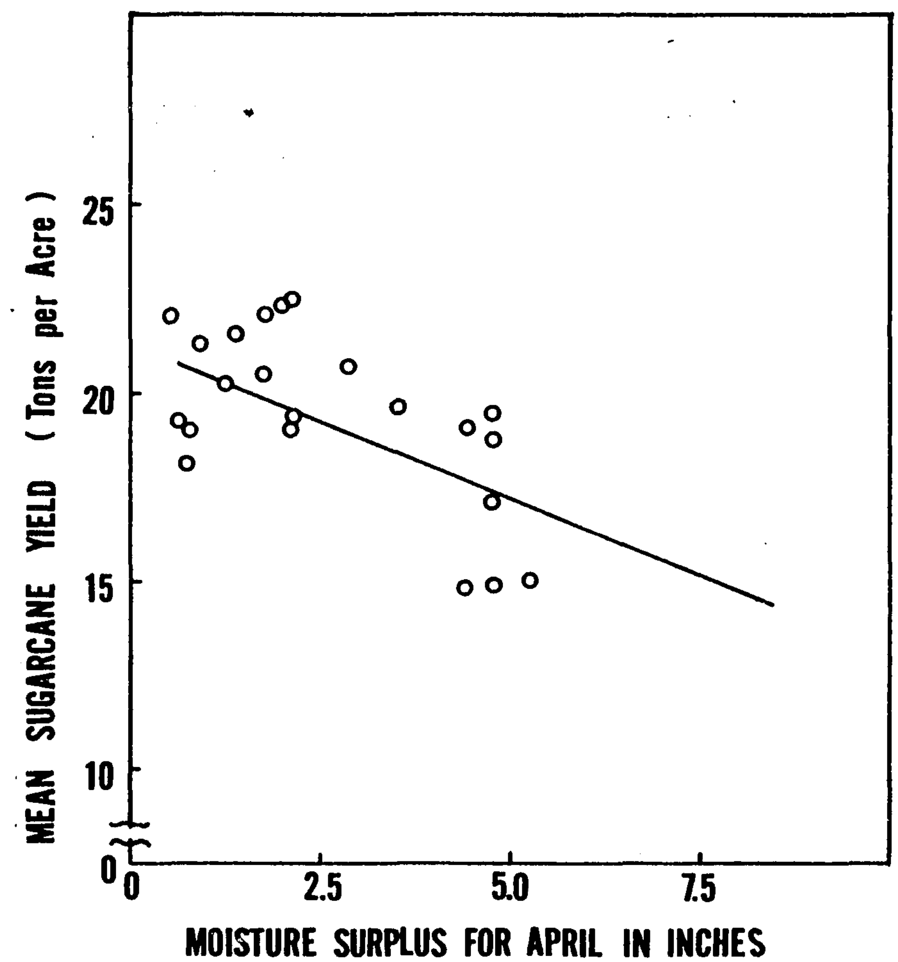

Figure 13. Relation of Mean Sugarcane Yield in St. Mary Parish and Soil Moisture Surplus for April for 1937-1960

with variables numbers 3, 13, 17 and 33. It gave a very high R^2 of .910 with only August temperature having a very highly significant t value of 12.706. None of the above variables were significant in the simple correlation analyses. The regression equation was:

$$y = -5.47 - 1.544X_3 - .553X_{13} - .300X_{17} + 2.379X_{33}$$

It was rather strange to note the change in the sigh of the standard partial regression coefficient for August temperature. On the basis of this analysis, an increase of 1.0°F in mean daily temperature for August led to an increase of 2.38 pounds of recoverable sugar per ton, if other variables tested were at uniform level.

St. Mary Parish was about the second most humid of all parishes studied. It did not have any drought and had a low mean deficit of 3.64 inches for July-September.

H) Terrebonne Parish. Results of correlation analysis for the period 1957-60 are given in Table 17. Cane yield was inversely related significantly with moisture surplus for March, variable number 3, and positively correlated with mean February temperature, variable number 27, and also with fertilizer nitrogen sales, variable number 40, in the parish ($r = .691$). Figure 14 shows the relationship of fertilizer nitrogen and yield. M.R. analysis was carried out with variables numbers 3, 4, 40, 35, 27 and 28, and gave an R^2 of .723. Moisture surplus in April, fertilizer nitrogen sales, and October temperature, had significant t values. The regression equation was:

$$y = 44.73 - 1.83X_3 - .53X_4 + .042X_{40} - .412X_{35} + .092X_{27} - .008X_{28}$$

Apart from the expected effect of fertilizer nitrogen, the analysis pointed out significant negative associations with surplus moisture in April and temperature in October.

Table 17. Correlation Studies of Sugarcane Yield and Sugar Per Ton for Terrebonne Parish, Louisiana for the Period 1937-60.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Sugar Per Ton
1.	Yield in Tons/Acre	20.18	.31		.361
2.	Sugar/Ton (Lbs.)	168.0	.87	.361	
3.	Moisture Surplus (Inches) - March	4.69	.44	-.407*	-.139
4.	Ditto - April	3.10	.23	-.362	-.202
5.	Ditto - May	2.20	.26	.058	.435*
6.	Ditto - June	2.52	.28	-.092	.342
7.	Ditto - July	2.68	.28	-.102	.299
8.	Ditto - August	2.80	.28	.049	.011
9.	Ditto - September	3.25	.38	.052	.130
10.	Ditto - October	1.52	.26	-.098	-.066
11.	Ditto - March-October	22.64	.96	-.314	.206
12.	Precipitation for November, December, January, February (Antecedent)	17.35	.58	-.271	-.111
13.	Precipitation for November (Current)	4.23	.48	-.552**	-.062
14.	Moisture Surplus Days - March	5.5	.33	-.305	-.093
15.	Moisture Surplus Days - March-May	11.5	.48	-.305	.069
16.	Moisture Surplus Days - September-October	4.8	.27	-.223	-.243
17.	Moisture Deficit (Inches) - May-September	2.49	.28	.0037	.140
18.	Moisture Deficit (Inches) - July-September	1.59	.24	.109	.370
19.	Moisture Deficit (Inches) - October	1.73	.64	.104	.399
20.	Moisture Deficit Days - May-September	7.7	.72		.125
21.	Moisture Deficit Days - July-September	4.4	.564	.111	.344
22.	Moisture Deficit Days - October	2.3	.707	.084	.424*
27.	Mean Temperature for February	58.6	.42	-.324	.051

Table 17. Continued.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
28.	Day Degrees for March	152.0	6.5	-.362	.009
29.	Mean Temperature for March	62.6	.33	.276	.130
30.	Lowest Weekly Minimum Temperature for April	53.0	.35	.164	-.056
31.	Day Degrees for April	289.0	5.5	.414*	.036
32.	Day Degrees for April-September	3229.0	14.2	.376	-.115
33.	Mean Temperature for August	81.8	.08	.0028	-.510
34.	Ditto - September	78.3	.17	.216	.0015
35.	Ditto - October	70.3	.31	-.368	.074
36.	Ditto - November	61.0	.27	.053	.096
37.	Number of Days After January 31 to Last Spring Freeze	24.1	2.5	-.041	-.269
38.	Number of Days After September 30 to First Fall Freeze	55.8	1.9	-.220	-.110
39.	Number of Days with Favorable Soil Moisture	209.0	1.1	.0974	-.363
40.	Nitrogen Fertilizer (Lbs./Acre)	59.5	4.3	.692**	.410

Level of significance for "r" at 5% P. - .404

Level of significance for "r" at 1% P. - .515

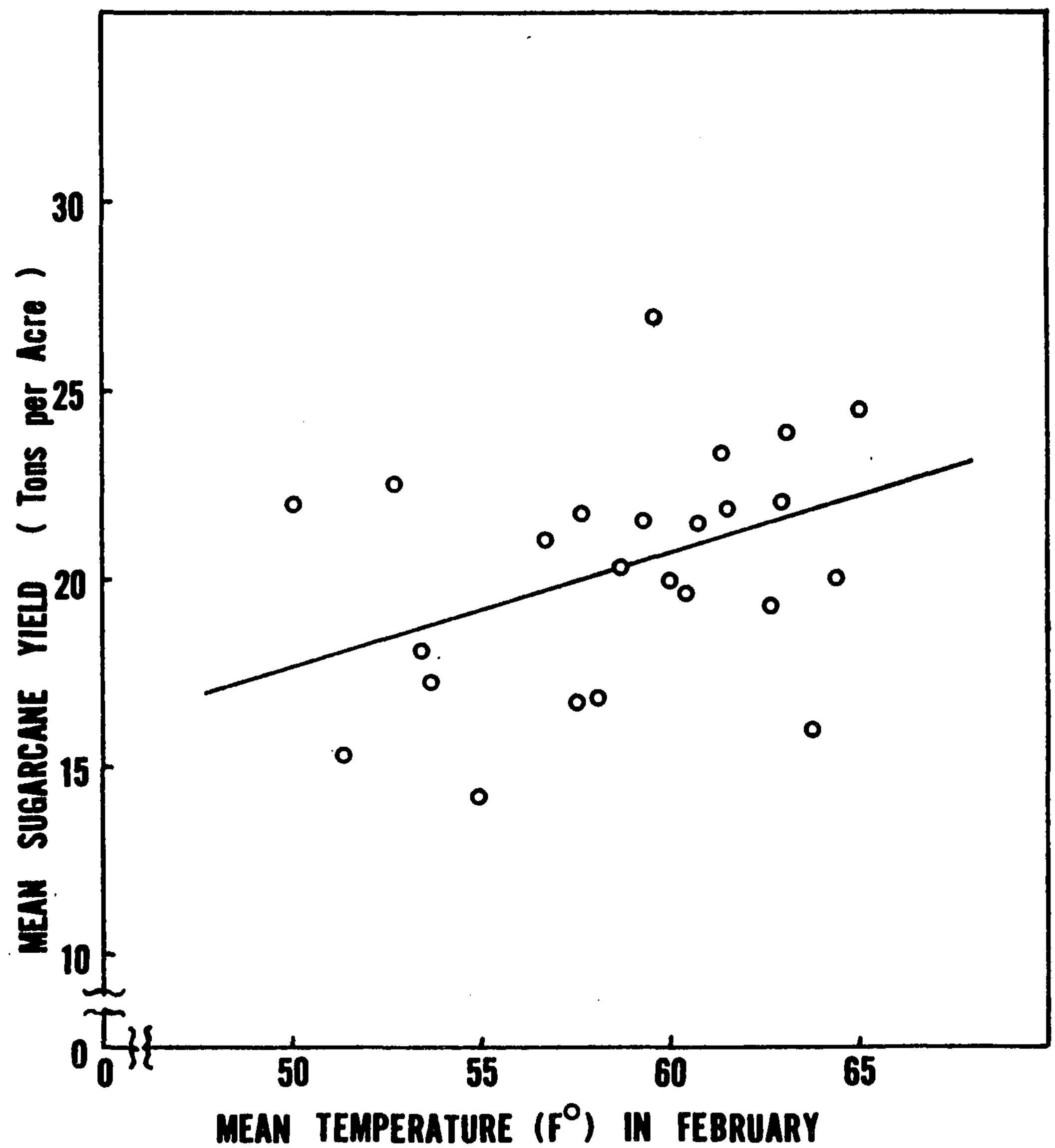

Figure 14. Relation of Mean Sugarcane Yield in Terrebonne Parish and Mean Temperature of February for 1937-1960.

Recoverable sugar per ton cane was noted to have a significant positive association with moisture surplus in March-May, and a negative one with August temperatures. Figure 15 shows the relationship graphically. Fertilizer nitrogen had also a positive association with sugar per ton of cane. This was rather unusual, particularly in view of its high positive association with cane yield also. M.R. analysis with variables numbers 15, 19, 33, 40, and 38 gave an R^2 of .696 with t value for moisture surplus in May, August temperature and fertilizer nitrogen as significant. The regression equation was: $y = 546.8 + 1.627X_5 + .288X_{19} - 4.552X_{33} - .070X_{38} + 0.69X_{40}$. It was noted that the sign for the standard partial regression coefficient for August temperature did not change in this analysis, indicating a net negative association.

Terrebonne is the third most humid parish. It did not have any drought and had only a mild moisture deficit.

I) West Baton Rouge Parish. Results of correlation analysis for the period 1937-60 are outlined in Table 18. Cane yield was inversely related with moisture surplus in March and positively with day degrees for April-September. Relation with moisture surplus in March is shown in Figure 16. M.R. analysis was run with variables numbers 3, 32, 8, 13, 27, 38, 31, and 40. It gave an R^2 of .609 with a significant t value only for moisture surplus for March which had a standard partial regression coefficient of -.604. This analysis revealed that about 39 per cent of the yield variations in this parish were due to some other important factors, not included in this relatively large number of parameters of soil moisture and temperature conditions.

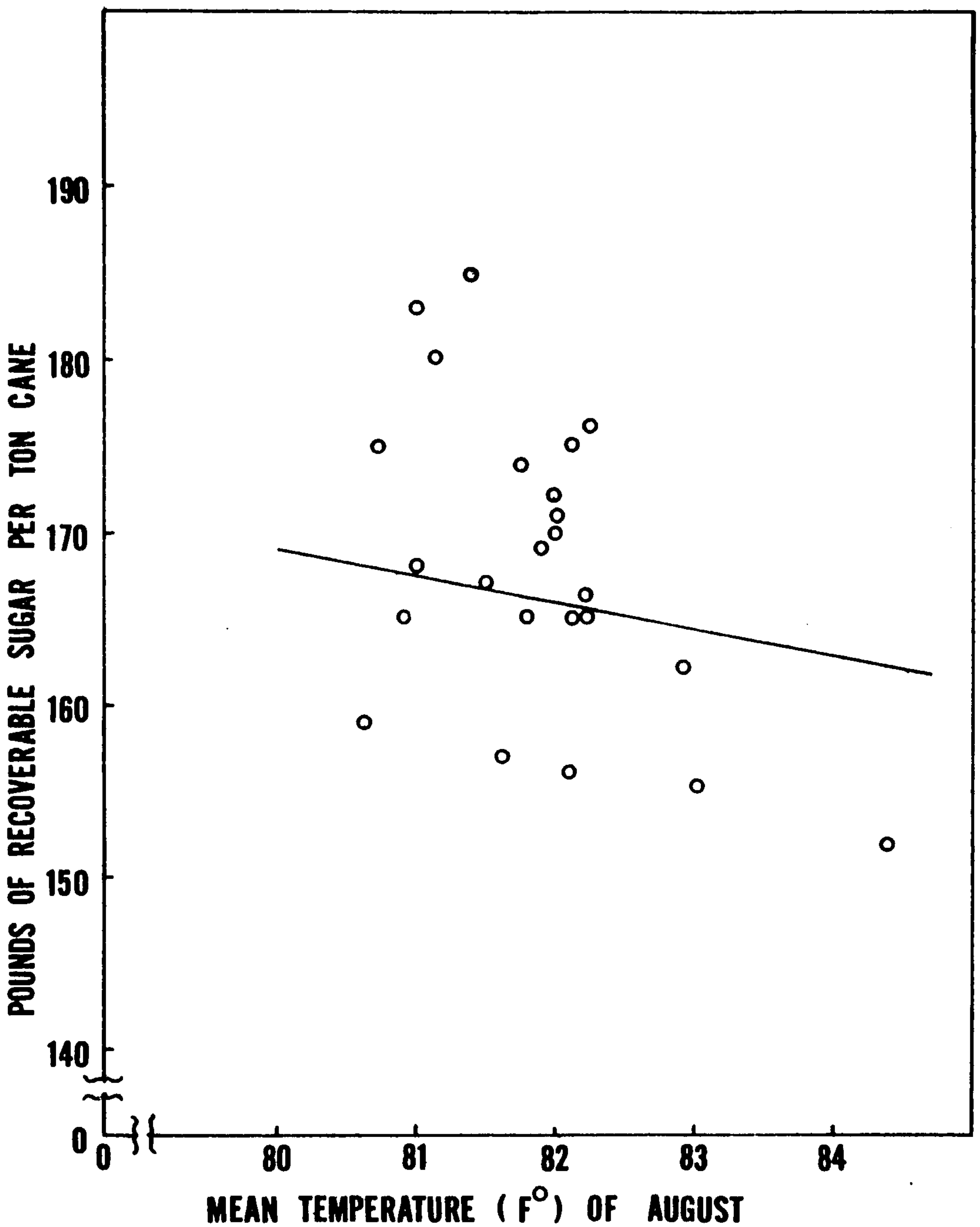

Figure 15. Relation of Mean Recoverable Sugar/Ton Cane in Terrebonne Parish and Mean Daily Temperature (F°) of August for 1937-1960.

Table 18 . Correlation Studies of Sugarcane Yield and Sugar Per Ton for West Baton Rouge Parish, Louisiana for the Period 1937-60.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
1.	Yield in Tons/Acre	21.51	.41		
2.	Sugar/Ton (Lbs.)	164.3	.70	.006	
3.	Moisture Surplus (Inches) - March	4.63	.35	-.470*	.136
4.	Ditto - April	3.70	.27	-.160	.130
5.	Ditto - May	3.28	.37	.149	.290*
6.	Ditto - June	1.00	.15	-.214	.460*
7.	Ditto - July	1.55	.27	-.069	-.165
8.	Ditto - August	1.10	.20	-.286	.016
9.	Ditto - September	1.09	.18	-.024	-.008
10.	Ditto - October	.53	.10	.137	-.215
11.	Ditto - March-October	16.88	.74	-.340	.263
12.	Precipitation for November, December, January, February (Antecedent)	19.37	.44	-.061	.153
13.	Precipitation for November (Current)	4.15	.33	-.308	-.038
14.	Moisture Surplus Days - March	6.7	.3	-.233	.177
15.	Moisture Surplus Days - March-May	14.4	.6	-.292	.407*
16.	Moisture Surplus Days - September-October	1.5	.3	.227	-.039
17.	Moisture Deficit (Inches) - May-September	19.94	2.45	-.051	-.014
18.	Ditto - July-September	17.52	2.36	-.070	.117
19.	Ditto - October	7.19	1.16	.170	.346
20.	Ditto -(Days)- May-September	29.9	2.78	.032	-.111
21.	Ditto - July-September	24.6	2.57	-.022	.070
22.	Ditto - October	11.3	1.25	.169	.244
23.	Drought (Inches) - June-September	.40	.15	-.330	.108
24.	Drought (Inches) - October	.13	.06	.139	.234
25.	Drought Days - June-September	1.6	.54	-.311	.126

Table 18. Continued.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
26.	Drought Days - October	.6	.29	.139	.236
27.	Mean Temperature for February	56.6	.42	.272	-.202
28.	Day Degrees for March	178.5	7.2	.269	-.150
29.	Mean Temperature for March	61.6	.38	.115	-.078
30.	Lowest Weekly Minimum Temperature for April	49.8	.33	.084	.157
31.	Day Degrees for April	333.0	6.3	.326	.006
32.	Day Degrees for April-September	3553.0	21.0	.435*	-.384
33.	Mean Temperature for August	82.0	.12	-.156	-.441*
34.	Ditto - September	78.0	.17	.014	.096
35.	Ditto - October	69.3	.32	-.263	.225
36.	Ditto - November	59.2	.25	.038	.174
37.	Number of Days After January 31 to Last Spring Freeze	27.5	1.7	-.087	-.358
38.	Number of Days After September 30 to First Fall Freeze	44.7	1.4	-.304	.300
39.	Number of Days with Favorable Soil Moisture	181.4	3.3	.062	-.060
40.	Fertilizer Nitrogen in Lbs./Acre	40.4	1.67	.341	-.210

Level of significance for "r" at 5% P. - .404

Level of significance for "r" at 1% P. - .515

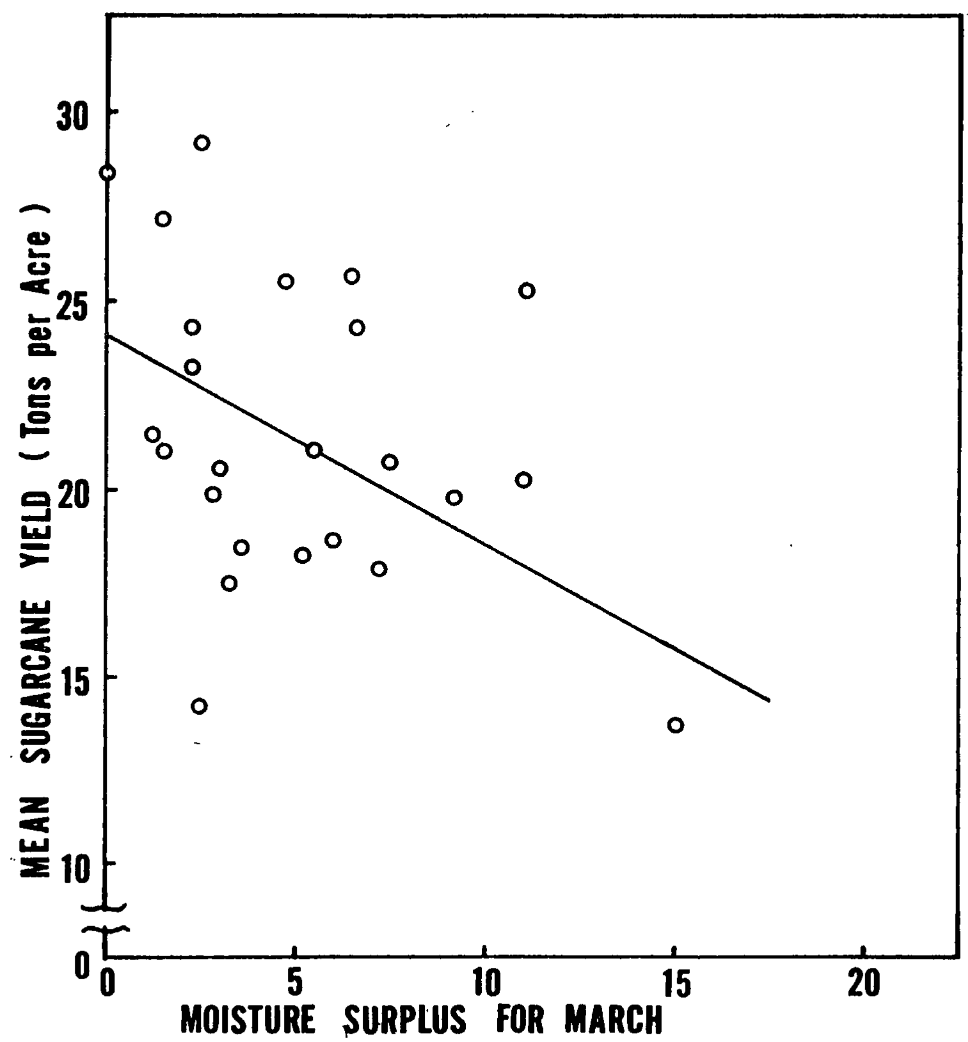

Figure 16. Relation of Mean Sugarcane Yield in West Baton Rouge Parish and Soil Moisture Surplus in Inches During March for 1936-1960

Recoverable sugar was positively related with moisture surplus in June and with moisture surplus days for March-May. Relationship with the surplus in June is given in Figure 17. It was negatively associated with August temperature. M.R. analysis with variable numbers 6, 15, 33, 37 and 38 gave an R^2 of .518 with moisture surplus in June only having a significant t value and a standard partial regression coefficient of 2.202 of negative sign. It was concluded that the positive association with the moisture surplus in June was due to the influence of other variables, and was by itself negatively associated.

West Baton Rouge Parish may be termed as representing a transition from humid to slight aridity. It had a relatively high total moisture surplus, but it also had a relatively high mean of 24.6 moisture deficit days in July-September.

J) Vermillion Parish. The period of the study extended over 1937-60 with the exception of 1949 and 1950. Results are presented in Table 19. Cane yield was inversely highly correlated with moisture surplus in March, total moisture surplus, with precipitation in November and with moisture deficit in May-September, July-September and October yield and days with favorable moisture had a high correlation coefficient (+.759). The relationship is shown in Figure 18. The cane yields in this parish appeared to be particularly responsive to the moisture regime. Moisture surplus in July was also positively related to yield. Multiple regression analysis with variables numbers 3, 7, 13, 19, 21, 39, 35, and 38 gave an R^2 of .721. None of the variables had a significant t value.

Recoverable sugar was positively related with moisture surplus

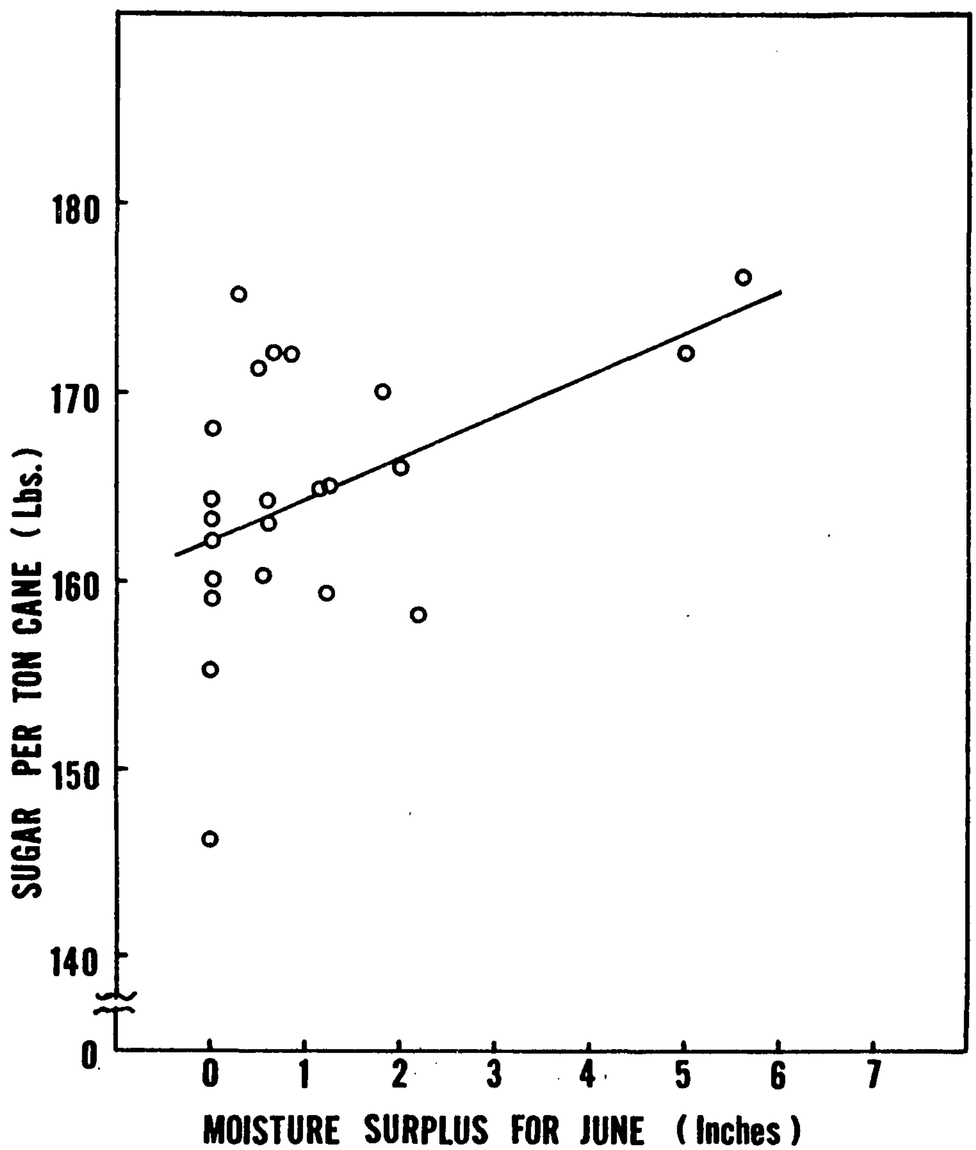

Figure 17. Relation of Mean Recoverable Sugar Per Ton Cane in Pounds and Soil Moisture Surplus in Inches for June During 1936-60. For West Baton Rouge Parish During 1937-60.

Table 19. Correlation Studies of Sugarcane Yield and Sugar Per Ton for Vermillion Parish, Louisiana for the Period 1937-60.[1]

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
1.	Yield in Tons/Acre	16.61	.34		.272
2.	Sugar/Ton (Lbs.)	162.6	.98	-.272	
3.	Moisture Surplus (Inches) - March	3.69	.30	-.619**	.351
4.	Ditto - April	2.44	.17	-.198	.088
5.	Ditto - May	2.73	.32	-.201	.392
6.	Ditto - June	2.06	.35	-.301	.100
7.	Ditto - July	2.31	.19	.467	-.343
8.	Ditto - August	3.05	.67	-.339	.071
9.	Ditto - September	1.92	.34	.127	-.184
10.	Ditto - October	1.05	.17	-.039	.056
11.	Ditto - March-October	19.26	.10	-.469*	.201
12.	Precipitation for November, December, January, February (Antecedent)	16.79	.42	-.148	.019
13.	Precipitation for November (Current)	4.36	.36	-.618**	.160
14.	Moisture Surplus Days - March	5.3	.29	-.259	.373
15.	Moisture Surplus Days - March-May	11.9	.40	-.156	.612**
16.	Moisture Surplus Days - September-October	2.8	.29	.056	-.226
17.	Moisture Deficit (Inches) - May-September	13.34	1.98	-.529*	.101
18.	Ditto - July-September	11.29	1.84	-.561**	.123
19.	Ditto - October	5.55	1.44	-.569**	.327
20.	Moisture Deficit Days - May-September	21.8	2.12	-.580**	.081
21.	Moisture Deficit Days - July-September	17.0	1.87	-.654**	.137
22.	Moisture Deficit Days - October	6.0	.98	-.511*	.258
23.	Drought (Inches) - June-September	.09	.03	-.278	.100
24.	Drought (Inches) - October	.54	.23	-.619**	.315

Table 19. Continued.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
25.	Drought Days - June-September	.8	.24	-.386	.182
26.	Drought Days - October	1.6	.56	-.606**	.335
27.	Mean Temperature for February	55.3	.42	.207	-.161
28.	Day Degrees for March	11.9	7.3	.201	-.219
29.	Mean Temperature for March	60.5	.39	.154	-.072
30.	Lowest Weekly Minimum Temperature for April	51.39	.35	-.018	.256
31.	Day Degrees for April	242.0	6.8	-.196	.321
32.	Day Degrees for April-September	3118.0	32.2	-.261	.192
33.	Mean Temperature for August	81.7	.13	-.302	-.112
34.	Ditto - September	77.6	.16	-.108	-.047
35.	Ditto - October	69.0	.33	-.374	.293
36.	Ditto - November	59.2	.28	-.207	.427*
37.	Number of Days After January 31 to last Spring Freeze	26.9	2.2	.030	-.346
38.	Number of Days After September 30 to First Fall Freeze	52.9	1.4	-.393	.416
39.	Number of Days with Favorable Soil Moisture	193.0	2.9	.759**	-.311
40.	Total E.T. in Inches (March-October)	25.07	.24	.270	.087

[1]Excepting 1949 and 1950.

Level of significance for 5% P. - .423

Level of significance for 1% P. - .537

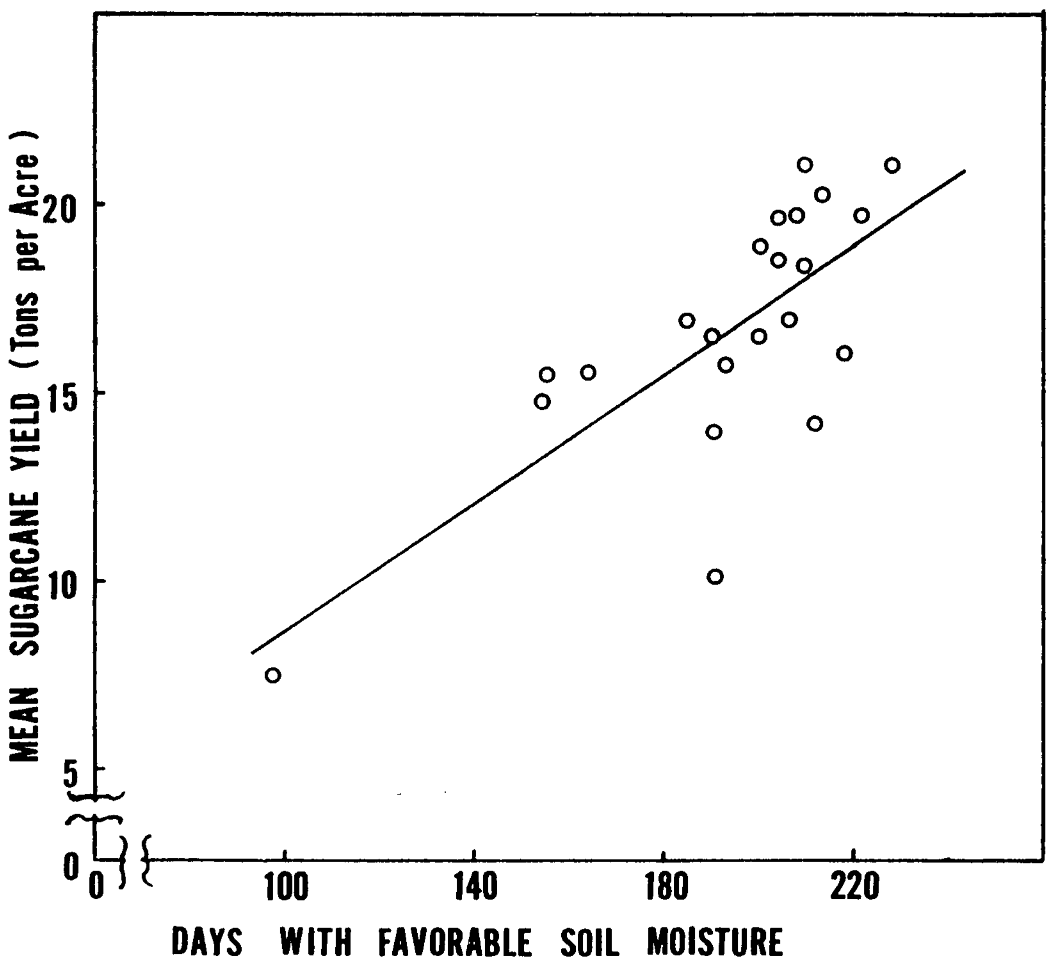

Figure 18. Relation of Mean Sugarcane Yield in Vermilion Parish During 1936-60 to Days With Favorable Soil Moisture From March Through October. During 1937-1960

days for March-May and mean November temperature. M.R. analysis with the above two variables and variables numbers 19, 31, 35, 37 and 38 gave an R^2 of only 0.499, with none of the variables showing a significant t value.

It is concluded from both the M.R. analyses carried out for this parish that the highly significant simple correlations of some variables were so interrelated that they did not show up in the multiple regression analysis.

Vermillion Parish had a fairly high total moisture surplus and moderate deficit. However the crop in this parish was responsive to both deficit and surplus moisture. It had the second lowest mean cane yield i.e. 16.60 tons.

<u>Comparison of soil moisture and temperature relationships of sugarcane in parishes</u>

A comparison of the relationships outlined for each parish above is afforded in Table 20. The parishes have been listed in the order of approximately decreasing water availability for the crop. The following points emerged from this comparative study:

1. Sugarcane yield was significantly associated negatively with moisture surplus in March (April in case of Terrebonne) for the first 6 parishes in Table 20 or up to the point of reaching a normal precipitation of 40 inches for March-October or 16 inches for July-September. Thereafter the association was not significant, although the trend was still there. Moisture surplus days were significantly associated positively with recoverable sugar per ton in the case of relatively less humid locations, viz. West Baton Rouge, Lafayette, Vermillion, Rapides and Pointe Coupee. The broad grouping that

Table 20. Summary of Moisture and Temperature Relationship in Sugarcane Area, Louisiana.

Crop Period and Variable	Assump.	Houma	St.Mary	Iberia	St.Char. St.James St.John	W.B.R.	Verm.	Laf.	Pointe Coupee	Rapides Avoy.
A. <u>Early Period</u>										
1. Precedent Rain	18.70	17.35	18.39	17.88	19.25	19.37	16.79	17.9	19.76	19.38
2. Moisture Surplus March	5.25*	4.69*	3.94*	4.40*	5.21*	4.63*	3.69*	4.11	4.11	4.55
3. Moisture Surplus (Days)-March-May	11.2	11.5	13.1	12.4*	14.5	14.4*	11.9*	13.2*	14.6*	13.7*
Significant "r" for Yield	-.574	-.407	-.616	-.614	-.455	-.470	-.619			
Significant "r" for Sugar						.407	.612	.555	.517	.519
4. February Temperature	57.9	58.6	57.3	55.6	55.5	56.6	55.3	55.9*	56.2	54.1
5. March Day Degrees	145.0	152.0	136.0	118.0	127.0	179.0	119.0	145.0	133.0	133.0
6. April Day Degrees	280.0*	289.0*	273.0	261.0	255.0	332.0	242.0	281.0	268.0	271.0
7. Spring Freeze Index	23.8	24.1	15.6	22.5	15.7	27.5	26.9	28.2	31.0	32.7
Significant "r" for Yield	.609	.414						.478		
B. <u>Growth Period</u>										
1. Moisture Deficit (Inches) July-Sept.	2.54	1.59	3.64	5.30	14.49	17.52	11.29*	11.39*	19.74	24.41
2. Moisture Deficit(Days) July-Sept.	8.5	4.4	9.1	13.3	20.6	24.6	17.0*	22.5	31.9	31.0
3. Moisture Deficit - July-Sept./Day of Deficit	.30	.36	.40	.40	.70	.71	.66	.50	.62	.79
4. Drought (Inches) - June September					1.8	1.6	.8	.14	.631	3.8
Significant "r" for Yield							-.654	-.424		
5. August Temperature	81.5	81.8*	82.0*	81.5*	82.5*	82.1*	81.7	81.9*	81.4	82.0*
6. Day Degrees-April-September	3277.0*	3229.0*	3138.0*	3004.0	3209.0	3553.0*	3118.0	3319.0*	3208.0	3356.0

Table 20. Continued.

Crop Period and Variable	Assump.	Houma	St.Mary	Iberia	St.Char. St.James St.John	W.B.R.	Verm.	Laf.	Pointe Coupee	Rapides Avoy.
Significant "r" for Yield	.609					.435		.438		-.476
Ditto - Sugar		-.510	-.422	-.500	-.517	-.441		-.626		
C. <u>Maturity & Harvest Period</u>										
1. Moisture Surplus-October	1.27	1.52	.68	.95	.88	.53	1.05	.82	.72	1.06
2. Moisture Deficit-October	2.88	1.73*	.42	5.11	5.23	7.19	5.55*	7.39	10.77	3.89
3. Ditto (Days)-October	4.2	2.3	3.3	6.5	8.2	11.3	6.0*	9.8	13.1	6.8
4. Drought Days (Oct.)					1.0	.6	1.6*	.7	2.4*	
5. Precipitation for November	3.76	4.23	4.40	3.88	3.81	4.15	4.36*	3.77*	3.85	4.95
Significant "r" for Yield		-.552	-.447				-.618	-.445		
Ditto - Sugar									.496	
6. Temperature for Oct.	69.2	70.3	70.3	69.1	70.1	69.3	69.0	69.4	68.1	68.3*
7. Ditto-November	59.7	61.0	60.5	58.7	59.6	59.2	59.1*	58.7	54.8	57.5
8. Fall Freeze Index	37.2	55.8	65.7	48.2	65.6*	44.7	52.9	49.9	41.7	44.3
Significant "r" for Sugar					.458		.427			.418
Total Surplus (March-October)	23.25	22.64	19.80	18.82	18.58	16.88	19.26	17.50	15.88	18.23
Precipitation utilized (Inches)	24.77	26.64	25.47	23.78	22.90	22.45	23.33	22.96	20.48	21.14
Total Normal Precipitation (Year)-Inches.	67.42	64.68	66.84	60.83	61.57	61.09	60.88	59.65	48.79	61.60
Ditto-March-October	48.05	46.78	47.82	42.28	42.52	40.09	41.55	38.18	36.60	39.64
Ditto-July-Sept.	21.13	22.16	21.99	19.12	17.59	16.21	18.22	15.32	13.19	13.67

emerged from the study was as under:

A) Humid: Assumption, Terrebonne, St. Mary and Iberia. No drought was noted in the period studied.

B) Sub-humid or Transient: St. Charles, St. James, St. John, and West Baton Rouge. Very mild drought occurred.

C) Sub-humid: Lafayette and Vermillion. Responsive to surplus as well as deficit moisture. However, M.R. analysis did not slow the negative association of deficit moisture.

D) Relatively Arid: Rapides, Avoyelles and Pointe Coupee. Moisture deficit was frequent and although simple correlation did not show it as significant, M.R. analysis showed yield of cane to be adversely influenced by it.

2. Temperature conditions in the early period and Day degrees for April had a positive significant association with cane yield in Assumption and Terrebonne. This was possibly due to high moisture surplus conditions. February temperature was positively associated with yield only in Lafayette. At other places it did not quite reach significant levels. In fact there was a trend for it to get less with drier conditions.

3. During the growth period, drought was noted in St. Charles, St. James, St. John, West Baton Rouge, Lafayette, Vermillion, Pointe Coupee and Rapides Parishes. In Vermillion and Lafayette data for moisture deficit gave significant negative total correlation with cane yield, but in Rapides it failed to reach the level of significance. Degree days for April-September had a positive association with yield in Assumption, West Baton Rouge and Lafayette. It was hard to explain this association. August temperature was significant in its effect on sugar per ton at all places except Rapides and Avoyelles and Assumption. In Rapides and Avoyelles it had a significant negative association with cane yield. Possibly excess

moisture conditions at Assumption prevented high temperature in August to have its influence, and adverse influence on cane yield counteracted the effect on sugar per ton. It appeared that temperature for August was very significant in influencing recoverable sugar, although in the multiple regression analysis, this was true only for Terrebonne, St. Charles, St. James, and St. John Parishes.

As regards maturity and harvest period, a moisture deficit in October in Terrebonne, St. Mary and Vermillion was negatively associated with yield. Heavier precipitation in November was significantly related negatively with yield of cane in St. Mary, Lafayette, Vermillion and Point Coupee. Mean temperature for October in Rapides and temperature for November in Vermillion had positive significant association with sugar content. In St. Charles, St. James and St. John only a significant positive effect of the fall-freeze occurring late was noted.

Effect of sunshine

The effect of hours of sunshine expressed as percentage of the possible sunshine as recorded at New Orleans City Weather Station, was studied in relation to the mean yield of cane and mean recoverable sugar per ton cane of the nearest sugarcane growing parishes, viz. St. Charles, St. James and St. John. Temperature and precipitation data were recorded at Reserve. The results are given below.

Table 21. Relation of Hours of Sunshine for New Orleans and Mean Sugarcane Yield, Recoverable Sugar, Mean Monthly Temperature and Mean Monthly Precipitation of St. Charles, St. James and St. John Parishes for the Period 1937-1960.

	Hours of Sunshine in % of Possible Hours		Correlation Coefficient of Hours of Sunshine With			
					Corresponding	
Period	Mean	Standard Deviation	Cane Yield	Recover. Sugar	Temp.	Precipitation
July	59.9	1.0	-.227	.025	.122	-.570**
August	65.5	0.6	-.058	-.179	.481*	-.234
September	62.8	1.2	-.091	.175	.195	-.672**
October	73.2	1.4	-.026	-.078	-.266	-.474*
November	61.1	1.1	.020	-.058	-.261	-.733**
Mean						
July-Sept.	63.6	0.7	-.230	.085		
Oct.-Nov.	67.4	0.7	-.005	-.123		

Sunshine hours, as recorded at New Orleans for any of the periods studied did not have significant effect on either the mean sugarcane yield per acre or the mean recoverable sugar per ton for the three parishes. The period July-September was regarded as representing growth conditions and October-November as the maturity period. As expected, temperature for August had a positive significant association with hours of sunshine. However, this was not observed to hold for July-September. October-November presented an opposite trend. Clear days probably provided better conditions for radiation losses and for lowering of temperature. Precipitation was related negatively to sunshine, as expected, and the association was significant at one per cent level of probability for July, September and November. The correlation coefficient was significant at five per cent level for October and insignificant for August. It was concluded that sunshine was not uniformly associated with precipitation over the five months studied.

<u>Effect of difference in available water storage capacity</u>

The results of the study with deep light textured Mhoon very fine sandy loam, of high available water storage capacity, and with Sharkey clay, a soil of relatively low available water storage capacity are presented in Tables 22 and 23, respectively. Total available water storage capacity of the soils was 5.1 and 2.5 inches, respectively. It was 1.4 and 1.3 inches, respectively between wilting point and 2 atmospheres of moisture tension. Correlation data relate to yield per acre of two varieties, viz. C.P. 44-101 and C.P. 36-105, both for plant cane and 1st stubble cane. The period of study was 1949-60. There was no data for 1958 for light textured soil. As expected, Sharkey clay had a larger mean deficit of moisture, 21.74 inches for May-September than Mhoon very fine sandy loam, 14.78 inches. The deficit in July-September was 12.55 and 8.94 inches for two soils, respectively. The moisture deficit of Sharkey tended to be negatively related with the cane yield of the stubble crop. There was no such trend on the Mhoon soil. On the light soil, plant cane yield of both the varieties was negatively associated with June surplus moisture while the stubble crop had a similar association with July surplus moisture. The surplus moisture did not show any significant negative relation on Sharkey soil. On the other hand, it tended to be positively related to stubble cane yield. Days with favorable moisture were significantly associated with stubble cane yield of C.P. 36-105. Mean temperature for August was significantly associated negatively with cane yield of C.P. 36-105 plant cane while mean temperature for November was positively related significantly with yield of the same variety. These relationships

Table 22. Correlation Studies of Sugarcane Yield and Sugar Per Ton for Mhoon Very Fine Sandy Loam Soil, Cinclare, Louisiana for the Period 1949-60.[1]

				Correlation Coefficient With Yield of			
				Plant		1st Stubble	
No.	Variable	Mean	Standard Deviation	C.P. 44-101	C.P. 36-105	C.P. 44-101	C.P. 36-105
1.	Yield Tons/Acre C.P. 44-101 - Plant	33.56	.69		.889	.493	.411
1a.	Yield Tons/Acre C.P. 44-101-Stubble	31.38	.60		.420		.933
2.	Yield Tons/Acre C.P. 36-105-Plant	32.55	.61				.327
2a.	Yield Tons/Acre C.P. 36-105-Stubble	27.78	.50				
3.	Moisture Surplus (Inches) - March	3.68	.27	-.048	-.142	-.229	-.328
4.	Ditto - April	3.59	.23	-.190	.005	.058	.005
5.	Ditto - May	3.65	.40	+.291	.249	-.218	-.232
6.	Ditto - June	.63	.15	-.635*	-.645*	-.312	-.186
7.	Ditto - July	1.51	.29	-.216	-.103	-.750**	-.756**
8.	Ditto - August	.33	.06	-.274	-.436	-.277	-.146
9.	Ditto - September	.31	.09	-.170	-.378	.306	+.341
10.	Ditto - October		.56	.223	.039	.077	+.132
11.	Ditto - March-October	14.26	.76	-.138	-.157	-.504	-.519
12.	Precipitation for November, December, January, February (Antecedent)	18.86	.37	+.453	+.498	-.150	-.058
13.	Precipitation for November (Current)	3.22	.23	.155	.134	.487	.425
15.	Moisture Surplus Days - March-May	14.1	.6	-.211	-.266	-.293	-.331
18.	Moisture Deficit (Inches) - July-September	14.78	1.77	.141	.143	.311	.361
19.	Moisture Deficit (Inches) - October	8.94	1.31	.073	.203	-.044	.042

Table 22. Continued.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient With Yield of: Plant C.P. 44-101	Plant C.P. 36-105	1st Stubble C.P. 44-101	1st Stubble C.P. 36-105
27.	Mean Temperature for February	57.4	.43	.014	-.055	.290	.309
28.	Day Degrees for March	182.0	6.6	.135	.312	.380	.340
29.	Mean Temperature for March	61.7	.35	.143	.314	.017	-.020
30.	Lowest Weekly Minimum Temperature for April	49.4	.32	-.125	.078	-.174	.026
31.	Day Degrees for April	334.0	6.5	.256	.117	.120	.319
32.	Day Degrees for April-September	3640.0	16.5	.178	.045	.150	.126
33.	Mean Temperature for August	82.1	.13	-.175	-.274	.033	-.137
34.	Ditto - September	78.1	.15	-.379	-.248	-.275	-.124
35.	Ditto - October	69.2	.34	-.184	-.142	-.499	-.325
36.	Ditto - November	58.8	.21	.121	.076	.183	.368
37.	Number of Days After January 31 to Last Spring Freeze	27.6	2.0	-.575	-.629*	.115	.170
38.	Number of Days After September 30 to First Fall Freeze	41.3	1.1	.164	.157	-.354	-.250
39.	Number of Days With Favorable Soil Moisture	181.0	2.3	-.054	-.060	-.208	-.221

Level of significance at 5% P. - .602

Level of significance at 1% P. - .735

Table 23. Correlation Studies of Sugarcane Yield and Sugar Per Ton for Sharkey Clay Soil, Cinclare Parish, Louisiana for the Period 1949-60.

				Correlation Coefficient With Yield of			
				Plant		1st Stubble	
No.	Variable	Mean	Standard Deviation	C.P. 44-101	C.P. 36-105	C.P. 44-101	C.P. 36-105
1.	Yield Tons/Acre C.P. 44-101-Plant	24.45	.53		.623	-.616*	-.227
1a.	Yield Tons/Acre C.P. 44-101-Stubble	25.32	.35		-.247		.462
2.	Yield Tons/Acre C.P. 36-105 Plant	22.28	.43				.011
2a.	Yield Tons/Acre C.P. 36-105 Stubble	20.85	.37				
3.	Moisture Surplus (Inches) - March	4.08	.30	.110	-.049	.066	-.318
4.	Ditto - April	4.14	.22	.079	.421	-.206	-.232
5.	Ditto - May	4.33	.41	-.455	-.017	+.421	-.065
6.	Ditto - June	1.38	.20	-.246	-.131	.021	-.336
7.	Ditto- July	2.97	.41	-.510	-.388	.529	.529
8.	Ditto - August	1.36	.14	+.125	.454	-.382	.193
9.	Ditto - September	1.22	.20	-.101	-.126	.076	-.077
10.	Ditto - October	1.11	.17	-.211	-.157	.422	.163
11.	Ditto - March-October	20.65	.93	-.467	-.107	.432	.017
12.	Precipitation for November, December, January, February (Antecedent)	19.04	.35	.012	.142	.239	.113
13.	Precipitation for November (Current)	3.11	.22	.074	.223	.004	.297
15.	Moisture Surplus Days - March-May	16.6	.7	.031	.001	.071	-.306
18.	Moisture Deficit (Inches) - July-September	21.74	2.14	.497	+.113	-.305	-.183
19.	Ditto - October	12.55	1.45	.215	+.366	-.380	-.488

Table 23. Continued.

No.	Variable	Mean	Deviation	Correlation Coefficient With Yield of			
				Plant		1st Stubble	
				C.P. 44-101	C.P. 36-105	C.P. 44-101	C.P. 36-105
21.	Moisture Deficit Days - July-September	34.7	2.8	.384	+.004	-.335	-.304
22.	Ditto - October	18.4	1.2	.348	+.269	-.536	-.321
27.	Mean Temperature for February	57.4	.43	.043	-.270	.162	-.141
28.	Day Degrees for March	182.0	6.6	.321	+.141	-.454	-.360
29.	Mean Temperature for March	61.7	.35	.253	.111	-.175	.211
30.	Lowest Weekly Minimum Temperature for April	49.4	.32	-.179	.300	.017	.519
31.	Day Degrees for April	334.0	6.5	-.191	.225	-.048	.083
32.	Day Degrees for April-September	3640.0	16.5	.035	-.061	-.286	.167
33.	Mean Temperature for August	82.1	.13	-.211	-.688*	-.020	-.204
34.	Ditto - September	78.1	.15	-.168	-.154	-.358	-.014
35.	Ditto - October	69.2	.34	.258	-.111	-.333	.027
36.	Ditto - November	58.8	.21	.215	.652*	-.249	.214
37.	Number of Days After January 31 to Last Spring Freeze	27.6	2.0	-.173	-.310	-.500	-.363
38.	Number of Days After September 30 to First Fall Freeze	41.3	1.1	.328	.508	-.232	.165
39.	Number of Days With Favorable Soil Moisture	142.0	3.3	-.337	-.032	.429	.545

Level of significance at 5% P. - .576

Level of significance at 1% P. - .708

were not noted on the light soil. C.P. 44-101 did not show this effect on either soil.

The above results showed that a considerable part of the differences in crop behavior on the two soil types could be related to their respective soil moisture regimes. Lack of association with surplus moisture on dry soil might be due to the surplus water having runoff with little infiltration and not causing poor aeration in the subsoil.

Effect of variety and planting

The mean cane yields per acre of C.P. 44-101 and C.P. 36-105 for plant and 1st stubble cane, as recorded in outfield test plots at four test fields, were studied in relation to soil moisture and temperature for the period 1949-60. The yield was an average of four replications.

1. Shirley Test Field, Bunkie: Results are given in Table 24. Mean yield of both the varieties, plant and stubble, was inversely correlated at one per cent level of probability with day degrees for April-September. Day degrees for March was also negatively associated with the yield of both varieties, both for plant cane and stubble at five per cent level of probability. Mean temperature for August was negatively related with C.P. 44-101 stubble but missed the level of significance slightly for C.P. 44-101 plant. Cane yield of C.P. 36-105 had poor association with August temperature. Yield of C.P. 44-101 stubble cane was also negatively associated with deficit moisture in May-September. C.P. 36-105 did not show this relationship.

This marked negative association of yield with temperature for the early as well as the growth-period on the Shirley test field

Table 24. Correlation Studies of Sugarcane Yield and Sugar Per Ton for Shirley Test Fields, Louisiana for the Period 1949-60.

				Correlation Coefficient With Yield of			
				Plant		1st Stubble	
No.	Variable	Mean	Standard Deviation	C.P. 44-101	C.P. 36-105	C.P. 44-101	C.P. 36-105
1.	Yield Tons/Acre C.P. 44-101-Plant	24.10	.83		.781	.913	.728
1a.	Yield Tons/Acre C.P. 44-101-Stubble	25.77	.62		.704		.686
2.	Yield Tons/Acre C.P. 36-105-Plant	23.08	.94				.957
2a.	Yield Tons/Acre C.P. 36-105-Stubble	23.55	.89				
3.	Moisture Surplus (Inches) - March	4.24	.23	.053	.350	.097	.452
4.	Ditto - April	4.73	.32	.162	.282	.098	.190
5.	Ditto - May	4.83	.81	-.311	-.181	-.378	-.151
6.	Ditto - June	.94	.12	.087	.181	.288	.193
7.	Ditto - July	.79	.15	.094	-.206	.170	-.333
8.	Ditto - August	.44	.01	.504	.331	.595*	.326
9.	Ditto - September	.44	.11	.230	.215	.446	.351
10.	Ditto - October	1.05	.11	.129	.371	.187	.408
11.	Ditto - March-October	17.46	.94	-.082	.121	-.068	.142
12.	Precipiation for November, December, January, February (Antecedent)	19.04	.35	-.169	.048	-.262	.040
13.	Precipitation for November (Current)	3.88	.38	.107	-.091	.108	.070
15.	Moisture Surplus Days - March-May	13.1	.4	.236	.563	.279	.522
16.	Ditto - September-October	1.8	.2	.104	.318	.120	.367
17.	Moisture Deficit (Inches) - May-September	27.85	2.63	-.440	-.300	-.575	-.321
18.	Ditto - July-September	20.03	1.58	-.455	-.261	-.579	-.270
19.	Ditto - October	5.08	.91	-.240	-.160	-.338	-.113

Table 24. Continued.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient With Yield of: Plant C.P. 44-101	Plant C.P. 36-105	1st Stubble C.P. 44-101	1st Stubble C.P. 36-105
20.	Moisture Deficit Days - May-September	43.3	3.2	-.448	-.278	-.630*	-.267
21.	Ditto - July-September	32.0	2.1	-.410	-.188	-.583*	-.171
22.	Ditto - October	8.1	1.2	-.374	-.273	-.410	-.235
23.	Drought (Inches)-June-September	.18	.05	-.198	-.336	-.170	-.398
24.	Ditto - October	.002		-.106	-.058	-.225	.013
27.	Mean Temperature for February ° F	53.8	.46	-.540	-.133	-.374	-.086
28.	Day Degrees for March	117.0	6.5	-.601*	-.611*	-.698*	-.621*
29.	Mean Temperature for March ° F	58.6	.41	-.380	-.257	-.504	-.287
30.	Lowest Weekly Minimum Temperature for April °F	48.7	.30	-.161	-.148	-.085	-.323
31.	Day Degrees for April	249.0	.72	-.442	-.555	-.364	-.520
32.	Ditto - April-September	3326.0	27.0	-.812**	-.747**	-.891**	-.726**
33.	Mean Temperature for August	81.7	.14	-.551	-.195	-.597*	-.212
34.	Ditto - September	77.1	.17	-.175	-.038	-.238	-.172
35.	Ditto - October	67.8	.28	.042	-.263	-.098	.245
36.	Ditto -November	56.6	.18	.214	-.139	+.369	-.058
37.	Number of Days After January 31 to Last Apring Freeze	44.4	1.3	.080	+.054	.029	.006
38.	Number of Days After September 30 to First Fall Freeze	29.8	2.0	-.229	-.298	-.199	-.324
39.	Number of Days With Favorable Soil Moisture	176.0	3.7	.475	.263	-.199	.227

Level of significance at 5% - .576

Level of significance at 1% - .708

was at variance with the data for Rapides and Avoyelles Parishes. However, lack of significant association of yield with moisture surplus for March or April was in common with the results for the parishes as a whole.

2. Houma Station. The results are presented in Table 25. The negative association of surplus moisture in March with yield, noted for Terrebonne Parish, was not observed for either of the two varieties. In fact C.P. 44-101 showed an opposite trend. This negative response was observed on plant cane only in July. The positive significant association of yield with April day degrees observed for the parish was also wanting, and instead a negative association of yield with April day degree was observed for C.P. 44-101 stubble. Yield of C.P. 36-105 stubble also had a negative significant association with March day degrees.

Effect of moisture status on cane yield and recoverable sugar for the entire area studied

In order to take advantage of a much larger number of observations, the data for each year for the parishes studied was utilized in a combined correlation analysis with 192 observations. This comprised data from the following:

Terrebonne, Lafayette, St. Charles, St. James, St. John, West Baton Rouge	24 years each
Vermillion, St. Mary and Iberia	22 years each
Pointe Coupee	17 years
Assumption	13 years

Results are set out in Table 26. Moisture surplus in June was negatively associated with yield but tended to have a reverse association

Table 25. Correlation Studies of Sugarcane Yield and Sugar Per Ton for Houma Station Varietal Trial, Louisiana for the Period 1949-60.

				Correlation Coefficient with Yield of			
				Plant		1st Stubble	
No.	Variable	Mean	Standard Deviation	C.P. 44-101	C.P. 36-105	C.P. 44-101	C.P. 36-105
1.	Yield Tons/Acre C.P. 44-101-Plant	27.62	.79			.425	
1a.	Yield Tons/Acre C.P. 44-101-Stubble	27.47	.61		.269		.195
2.	Yield Tons/Acre C.P. 36-105-Plant	25.52	.77				.353
2a.	Yield Tons/Acre C.P. 36-105-Stubble	23.14	.63				
3.	Moisture Surplus (Inches) - March	4.65	.43	.382	-.558	.419	-.073
4.	Ditto-April	3.50	.21	.225	.078	.510	.325
5.	Ditto-May	2.64	.33	-.463	-.303	-.139	-.041
6.	Ditto-June	2.82	.27	-.200	-.225	-.088	-.177
7.	Ditto-July	2.77	.33	-.635*	-.609*	-.406	-.423
8.	Ditto-August	2.84	.27	-.139	.100	-.307	-.132
9.	Ditto-September	2.37	.33	+.092	+.233	.318	+.269
10.	Ditto-October	1.70	.23	-.530	-.324	-.393	-.206
11.	Ditto-March-October	23.03	1.01	-.307	-.051	.037	-.116
12.	Precipitation for November, December, January, February (Antecedent)	16.73	.43	-.426	-.354	.155	-.550
13.	Ditto-November (Current)	2.78	.33	-.117	-.111	-.171	-.359
14.	Moisture Surplus Days-March	5.8	.4	+.567	.566	.465	.258
15.	Ditto-March-May	12.8	.6	+.549	.468	.549	.206
16.	Ditto-September-October	4.3	.3	+.067	.388	.224	.218
17.	Moisture Deficit (Inches)-May-September	2.59	.31	-.374	-.529	-.126	.050
18.	Ditto-July-September	2.36	.28	-.366	-.517	-.188	.013
19.	Ditto-October	3.44	.39	-.085	-.183	-.182	-.338

Table 25. Continued.

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Yield of: Plant C.P. 44-101	Plant C.P. 36-105	1st Stubble C.P. 44-101	1st Stubble C.P. 36-105
20.	Moisture Deficit Days-May-September	7.6	.8	-.255	-.487	.005	.225
21.	Ditto-July-September	6.3	.6	-.205	-.449	-.110	.183
22.	Ditto-October	4.3	.9	.057	-.150	-.055	-.276
27.	Mean Temperature for February	59.3	.44	-.123	-.154	.247	-.294
28.	Day Degrees for March	144.0	2.5	.004	-.098	-.175	-.544
29.	Mean Temperature for March	62.3	.26	-.109	-.109	-.107	-.641*
30.	Lowest Weekly Minimum Temperature for April	52.8	.32	-.333	-.286	-.688*	-.036
31.	Day Degrees for April	281.0	6.4	-.259	-.148	-.726**	-.156
32.	Ditto-April-September	3230.0	12.0	-.013	.073	-.577*	.161
33.	Mean Temperature for August	81.8	.10	.117	.246	.251	.224
34.	Ditto-September	78.5	.14	-.067	-.063	-.407	-.320
35.	Ditto-October	70.4	.33	-.030	.095	-.304	-.492
36.	Ditto-November	60.7	.24	.105	.345	-.589*	.221
37.	Number of Days After January 31 to Last Spring Freeze	15.8	2.1	.184	.179	-.308	.029
38.	Ditto-September 30 to First Fall Freeze	51.0	2.1	-.093	.095	-.526	-.307
39.	Number of Days With Favorable Soil Moisture	207.0	1.3	.263	.222	.260	.130

Level of significance at 5% P. - .576

Level of significance at 1% P. - .708

Table 26. Correlation Studies of Sugarcane Yield and Sugar Per Ton for Assumption, Iberia, Pointe Coupee, Lafayette, St. James, St. Mary, Terrebonne, West Baton Rouge and Vermillion Parishes, Louisiana for the Period 1936-60.[1]

No.	Variable	Mean	Standard Deviation	Correlation Coefficient with Cane Yield	Correlation Coefficient with Sugar Per Ton
1.	Yield in Tons/Acre	19.76	.431		.470
2.	Sugar/Ton (Lbs.)	17.18	3.21	-.470**	
3.	Moisture Surplus (Inches) - March	4.37	.34	-.132	.072
4.	Ditto - April	3.36	.24	-.054	.059
5.	Ditto - May	2.78	.34	-.007	.048
6.	Ditto - June	1.87	.25	-.152*	.138*
7.	Ditto - July	2.11	.27	-.070	-.0004
8.	Ditto - August	1.98	.40	-.179*	.040
9.	Ditto - September	1.70	.31	.072	.081
10.	Ditto - October	0.93	.18	-.027	.024
11.	Ditto - March-October	19.06	.89	-.192**	.150*
12.	Precipitation for November, December, January, February (Antecedent)	18.33	.47	-.054	-.083
13.	Precipitation for November (Current)	4.4	.34	-.209	-.089
14.	Moisture Surplus Days - March	6.0	0.3	-.058	.064
15.	Ditto - March-May	13.0	0.5	-.085	.151*
16.	Ditto - September-October	2.8	0.3	.098	.073
17.	Moisture Deficit (Inches) May-September	11.49	1.58	-.084	-.155*
18.	Ditto - July—September	9.60	1.45	0.097	-.126
19.	Ditto - October	4.84	1.05	.038	.003

[1]Period not uniform for all parishes. Please see text for details.

Level of significance for "r" at 5% P.

Level of significance for "r" at 1% P.

with recoverable sugar. Surplus moisture in August and total surplus moisture (March-October) had also a negative significant association with cane yield. These results were in general agreement with the parishes, though the considerable variation between them served to mask the differential response.

Similar study with mean monthly temperatures for all the 12 weather stations with cane yield and sugar per ton of corresponding parishes gave a significant r of .137, .208, .128 and -.162 for the mean monthly temperature of January, February, March and October. This analysis had 277 observations and a level of significance for r as .119 at five per cent level of probability. It appears that the large number of observations served to bring out the positive association of mean February temperature.

Some factors of soil moisture studies in the parishes

Almost all parishes were subjected to very heavy downpour at some time during the 8 months of the year covered by this study. Abbeville (Vermillion Parish) was more subjected to heavy rains. Lafayette had the heaviest surplus of 34.29 inches in August, 1940. Franklin had 14.3 inches rain on September 16, 1942 and 11.55 on July 29, 1954.

The highest precipitation, 72 inches, for March-October recorded during the period of study was at Abbeville in 1940 with a surplus of 50.50 inches. Melville representing Pointe Coupee Parish, had a total moisture surplus of only 8.18 inches from March-October in 1945, and a surplus of 25.89 inches for May only in 1953. In Rapides, the soil moisture fell to the lowest level, 1.28 inches below wilting point, on September 15, 1947. At this level of moisture the calculated E.T. was .03 inches per day. During the period of study, the years 1947 and 1951 had low total and poorly distributed rainfall. The period 1946-1949 was marked by rather heavy March rains. Considerable variation existed between parishes in all the years.

DISCUSSION

Before discussing the results presented in the last chapter, it will be helpful to outline the limitations that this study suffered, since any observations made on the basis of this study must be viewed in the light of these limitations.

Weeds exercised a great influence on the crop behavior through their effect on soil moisture, nutrient uptake and in certain other ways. The introduction of 2,4-D in 1945 had its impact on dicots and broadleaved weeds. Use of T.C.A., Dalapon, etc. started having its influence toward the last 3 years of the period of this study. It was not possible to evaluate the influence of weeds either for the state or parishes for lack of data (102). The variable influence that weeds had on the crop might have affected the relations of other variables.

Although there was not any serious disease outbreak during the period of study, the variations due to diseases probably figured in the correlational analysis of cane yield and sugar per ton and affected the conclusions drawn.

The crop was grown on soils which were fairly different in texture, structure, origin and fertility, as for example Richland, Olivier, and Cypremort series in comparison with Sharkey, Mhoon, Commerce and Yahola. It is likely that the generally lower yields in Lafayette Parish were due to differences in soil.

The soil moisture studies assumed infiltration and absorption of rain water to the point of the available water-storage capacity, with the complete runoff of any additional rainfall. As previously explained, intensity and duration of rainfall and soil conditions affecting rate of infiltration, influenced the funoff. It was also explained that at times water was held over and above the field capacity.

The soil moisture studies assumed a uniform soil surface covered with sugarcane vegetation, less in March but complete by July. Actually conditions of a sugarcane field in Louisiana are very different. The ridge covers a width of 1-2.5 feet and has much higher pore space and is sloping while the rest of the 3.5-5 feet of the row width comprised the middle which has less pore space, and higher bulk density. A traffic pan generally exists at the middle's bottom. This picture changes somewhat from time to time due to cultivation and rain. Rates of infiltration on the ridge and the remainder of the row must have differed considerably. Soil moisture and temperature conditions also must have differed. It is likely that heavy showers might have runoff without the porous and possibly dry ridge having enough moisture to pick up to field capacity. In short the assumptions made in regard to absorption of rain water and its availability to sugarcane are not fully valid, although this is still the best that can be done in the absence of critical data on the physical properties of a sugarcane field.

In view of the above limitations, it was not a surprise to find multiple coefficient of determination of the order of 0.41 to 0.58 in some cases for all the significant and important variables tested. Relatively low values of R^2 were noted for relations of sugar per ton cane indicate that in such cases, the limitation exercised a conspicuous part. However, the very high R^2 of 0.911 with mean August temperature and 3 other variables indicates that even sugar per ton was markedly associated with August temperature and moisture conditions of both the early and the maturity period.

The search for a suitable period for this study indicated that conditions of sugarcane cultivation in Louisiana in 1919-35 were significantly different from those in 1936-60, as far as relation with climate was considered. This was probably due to practice of using windrowed cane seed on a large scale in the earlier period and to varieties bred for this area, as was pointed out by Brandes (117). This difference of conditions also accounts for the results of this study being different from those reported by MacDonald (74).

The results of the study pointed out an important association of cane yield and recoverable sugar with soil moisture conditions. The negative association of soil moisture surplus in the early period of crop growth was significant in all the parishes studied with the exception of Lafayette, Pointe Coupee and Rapides and Avoyelles. When soil moisture surplus was not negatively associated with yield, it was positively associated with recoverable sugar, except in West Baton Rouge and Vermillion where this positive association with recoverable sugar existed in spite of negative association with cane yield. Surplus moisture exercised its influence probably through its effects on soil temperature and aeration. The negative association of yield with soil moisture surplus in the early period was shown even in M.R. analysis for Iberia, St. Mary, Terrebonne and West Baton Rouge. This analysis was not carried out for Assumption Parish due to lower number of observations but possibly it would have given similar results. It appeared that the four parishes listed above had a net negative association of moisture surplus in the early period with cane yield.

Lack of significant association of yield with early moisture surplus in Rapides and Avoyelles, Pointe Coupee and Lafayette might have possibly been due to lower soil moisture and other soil conditions. The trend was negative for these parishes, although it failed to reach the significant level.

Soil moisture conditions during the active growing period in the parishes studied differed more than they did in the early period. The total mean moisture surplus for July-September period was 5.72 to 8.78 inches in the four humid parishes and Vermillion. It was 2.05 to 2.62 inches in Pointe Coupee, Rapides and Avoyelles Parishes. With the exception of Vermillion Parish, high moisture surplus in July-September was associated with lack of negative relationship of mean August temperature with sugar per ton cane. Low precipitation, during July-September in Rapides, Avoyelles and Pointe Coupee Parishes, was associated with a high mean maximum temperature for these months and differences in moisture surplus probably did not play any direct role. This may be taken as the direct result of continentality effect on Rapides and Avoyelles Parishes.

It is significant that cane yield was negatively associated with moisture deficit only in Vermillion and Lafayette and not in Rapides and Avoyelles or Pointe Coupee, in spite of a much higher moisture deficit and a considerably lower mean moisture surplus. Multiple regression analysis, of cane yield in Rapides and Avoyelles however, showed it to be positively related with days of favorable moisture. Differences in nature of soil and the occurrence of heavy downpours in Vermillion might have been responsible for bringing about this effect to some extent.

Wet conditions at harvest caused by precipitation in November were significantly associated negatively with cane yield in Terrebonne, St. Mary, Lafayette, Vermillion, and Pointe Coupee, but failed to reach a level of significance in other parishes. In the combined correlation analysis for all parishes, the r value was -.209, significant at one per cent level of probability. Wet conditions in November probably depressed the yield through poor harvest and loss of cane already in the field. Lack of association of precipitation in November with recoverable sugar per ton of cane was probably due to the crop being already immature.

Moisture deficit reported in this investigation corresponded to an available soil moisture less than 1.50 inches for a soil with 4.0 inches storage capacity and may be equated with the level of "drought," according to the concept of Van Bavel (123) or Holcombe (53). For purposes of supplemental irrigation, the moisture deficit days during July-September should provide a good guide. Rapides and Avoyelles Parishes had the largest number of 31 mean moisture deficit days with 0.71 inches as mean available water for this period. Terrebonne Parish had only 4.4 mean moisture deficit days with 1.14 inches as mean available water for this period. Correlation of moisture deficit and moisture deficit days with yield indicated that yield was adversely influenced in Lafayette, Vermillion, Rapides and Avoyelles Parishes. As such supplemental irrigation is likely to be worthwhile in these parishes. However, lack of association of moisture deficit with yield in West Baton Rouge, Pointe Coupee, St. Charles, St. James and St. John Parishes was noted. A resort to supplemental irrigation is, therefore, not suggested in these parishes. Conditions in the rest of the four parishes are more humid and need for irrigation is not indicated either by soil moisture data or by the relationships of moisture deficit with cane yield.

The results of relatively low evapo-transpiration of sugarcane in Louisiana determined by soil moisture method were fairly alike. The water requirement of sugarcane is low until about the end of June due to low leaf surface. A rise in relative humidity, cloudiness and a decrease in wind velocity during the active growth period serves to keep E.T. losses low. Water use by the crop depended very largely on the amount and distribution of the rainfall.

Correlation studies of soil moisture data in this study pointed out a number of cases where the results of soil moisture computation appeared to be doubtful. Although the modulated P.E. method developed in this study was fairly well suited to the four basic data utilized, it is felt that a better assessment of the available water storage capacity of different soils in the parishes will yield harmonious results even for these cases. Results of cane yields on test fields on Mhoon very fine sandy loam and on Sharkey clay and only about a mile apart, lend support to the above idea.

It was rather surprising to find lack of association of yield with spring temperatures, except in Assumption, Terrebonne and Lafayette, although in each of the other parishes February temperature tended to have a positive correlation with cane yield. Spring freeze index did not show significant relation with yield in any parish. It is to be kept in mind that the data used in the study was mean air temperature. The relationship of air temperature to soil temperature which actually influences the crop is much conditioned by soil moisture, bulk density, etc. It is likely that soil temperature conditions did not differ too much, or were not too unfavorable, because of the cambered beds with the sugarcane near the ridge tops.

Mean temperature of about 56^{o} and $62^{o}F$ for February and March reported was relatively low for good germination, according to Hawaiian standards. Relatively high maximum temperature and micro-relief of the sugarcane field were probably conducive to a relatively high temperature of the root zone. This view is supported by a positive association with day degrees for March and April in a number of parishes.

The study provided fairly clear evidence that temperature in August reached a high enough level to have significant negative association with recoverable sugar in six of the parishes studied and failed to reach significant level in the rest. In Rapides and Avoyelles, it was negatively associated with yield of cane. The mechanism of this association is not well understood although multiple regression analysis indicated that it was not uniform. It could have been possibly through poor light intensity in relation to temperature, as per findings of Loraentz, et al. (68), or through its effect on diseases or insects, although very little is known about either of these. This important association of August temperature with recoverable sugar should be looked into for the nature of the mechanism and for possible means to get over the adverse associations.

Temperature conditions at harvest were significantly associated with recoverable sugar per ton only in St. Charles, Vermillion and Rapides and Avoyelles Parishes. In general the association was poor, being negative with yield and positive with recoverable sugar. Reasons for the temperature conditions being significant in three parishes only cannot be offered without more evidence.

The results of correlation studies with mean cane yield of test fields with two varieties, both for plant and first stubble gave indications of C.P. 44-101 being nonresponsive to soil-moisture changes. Stubble cane was noted to be less affected by early period surplus. However, these data gave some highly significant relations with mean February and March temperature, which were directly at variance with general results for the parish in which these were located. This was probably due to conditions of test fields being not representative of the general crop. Further the data related to only 12 years. It is felt that data of test fields could not be utilized for studying the behavior of the general crop. The advantage of having the same variety for the entire period of study appears to be more than offset by differences in soil management and other agronomic practices, and the generally shorter period available.

CONCLUSIONS

On the basis of results reported and the discussion of the the same, the following conclusions are drawn.

Change in conditions of cultivation of sugarcane and in the varieties grown was probably responsible for the crop being not susceptible to precedent rainfall during 1936-60. The cane yield was also less responsive to spring temperature, but had a marked negative association with moisture surplus in March or April. Further efforts should be directed towards evolving varieties and agronomic practices less susceptible to moisture surplus.

The association of temperature for early period with cane yield is highly related to moisture surplus conditions. A study of the physical properties of soil, soil temperature, related growth data of cane and losses of nutrients by leaching or otherwise should be undertaken to study the exact influence that surplus soil moisture has on the crop. The results of such a study should be useful in devising ways and means to get over the undesirable effects.

The strong negative association of mean August temperature with sugar per ton suggests that summer temperatures in the sugarcane area are too high for proper sugar storage. The physiology of sugar synthesis and storage in Louisiana in particular relation to summer temperature deserves to be studied. The meagre available data for sunshine did not show any definite association with sugar per ton or cane yield.

On the basis of soil moisture computation and correlation studies of soil-moisture deficit with cane yield, supplementary irrigation is considered worthwhile in Lafayette, Vermillion, Rapides and Avoyelles Parishes. Assumption, Iberia, St. Mary and Terrebonne did not show any need for irrigation.

The studies reported indicated water requirement of the sugar-cane crop in Louisiana to be about 22-26 area inches. Relatively low water use is due to rise in humidity, decrease in wind-speed and increased cloud cover during the active growth period of the crop. Water usage is low until the end of June because of the crop covering the ground only partly. Need for collecting basic data for evapotranspiration of the crop has been pointed out.

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APPENDIX

Appendix Table 1. Quantity of Fertilizer Nitrogen Sold in Tons in the Sugarcane Area, Louisiana for the Period 1936-1960.

Year	St. Mary	Terrebonne	West Baton Rouge	Total for 18 Sugarcane Growing Parishes
1936-36*	N.A.	N.A.	N.A.	3,600.0
1936-37*	460.0	450.0	160.0	4,800.0
1937-38*	460.0	450.0	160.0	4,700.0
1938-39	469.4	461.5	161.9	4,350.1
1939-40	297.0	419.1	169.0	4,199.2
1940-41	365.4	487.2	172.3	4,406.7
1941-42	407.9	445.6	178.6	5,092.5
1942-43	425.8	479.5	196.9	5,218.1
1943-44	544.1	548.1	197.9	6,718.3
1944-45	532.9	600.7	197.9	6,722.1
1945-46	570.8	533.5	251.5	7,248.6
1946-47	664.7	451.8	196.3	7,800.6
1947-48	492.8	685.5	226.8	7,530.2
1948-49	582.9	717.8	193.0	7,351.1
1949-50	733.1	553.3	336.6	10,337.1
1950-51	748.0	725.1	307.6	12,390.9
1951-52	1,742.8	973.4	386.2	15,865.1
1952-53	581.2	1,994.2	183.2	12,580.7
1953-54	1,196.9	1,887.4	193.2	17,935.0
1954-55	626.9	2,436.0	168.3	16,595.3
1955-56	643.7	1,681.1	280.0	18,970.0
1956-57	412.8	1,406.1	359.9	21,163.5
1957-58	253.5	572.9	289.6	13,836.7
1958-59	1,206.5	865.8	603.9	19,735.0
1959-60	1,542.7	822.0	269.3	20,964.4

*Data for these 3 years was estimated from total sales for the state, on the basis of sugarcane area constituting 39 per cent of the total sales of fertilizer nitrogen in the state. Details of sales in parish were not available for these 3 years.

VITA

Girdhari Lal was born on August 20, 1912 at Village Doda, District Sargodha, West Pakistan. He received his High School education at S. D. High School, Sargodha, affiliated to the Panjab University. He studied for two years at Khalsa College, Amritsar, Panjab, India for his First Examination in Agriculture of the Panjab University during 1930-1932. The next two years at Panjab Agricultural College, Lyallpur, West Pakistan led him to receive his B.Sc.(Agri.) of the Panjab University in 1934, majoring in Agriculture and Chemistry.

He started his career as Research Assistant in Irrigation Research Institute, Lahore (West Pakistan) in 1934 and married in September, 1934. In 1935 he joined Panjab Agricultural Department and worked as Research Assistant for 8 years at Panjab Dry Farming Research Station, Rohtak, India and for 3 years in Chemical Research Laboratories of Pb. Agri. College, Lyallpur. While at Rohtak, he worked up for his M.Sc.(Agri.) in Soil Science of the Panjab University, Lahore in 1942.

He resigned his position in the Department of Agriculture of the Panjab Government in June, 1946 to work as Fertilizer Officer for D.C.M. Chemical Works, Delhi - a subsidiary of the Delhi Cloth and General Mills Co., Delhi. In 1952 he was transferred to Daurala Sugar Works, Daurala, also a subsidiary of Delhi Cloth and General Mills Co., Delhi, to work on Sugarcane Research and Development work. He proceeded on study leave in January, 1961 to Louisiana State University, Baton Rouge, La., and is now a candidate for the Ph.D. degree.

EXAMINATION AND THESIS REPORT

Candidate: Girdhari Lal

Major Field: Agronomy

Title of Thesis: Yield of Sugarcane in Louisiana as Influenced by Soil Moisture Status and Climate

Approved:

Wm. H. Patrick, Jr.
Major Professor and Chairman

Max Goodrich
Dean of the Graduate School

EXAMINING COMMITTEE:

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Date of Examination:

July 11, 1962